Kenya County Climate Risk Profile: Trans Nzoia County

Highlights

- High-input, rain-fed mechanized agriculture is the main livelihood source in Trans Nzoia County (Figure 1), contributing about 70% of an average household's income.
- Maize, beans, dairy cow , and indigenous chickens are the key value chain commodities that contribute to household food security and livelihoods.
- Uncertainty about the growing season, including about the onset and end of the rainy season, moisture stress, and excess rainfall are the main climatic hazards that affect productivity along these value chains, thus compromising food security in Trans Nzoia.
- Declining land productivity, high input costs, low producer prices, inadequate extension services, insufficient storage and processing facilities, little or no value addition, and inadequate markets and marketing infrastructure are some of the outstanding factors that aggravate the adverse impacts of climate change and variability, limiting farmers' capacities to cope with these impacts.
- Farmers employ on-farm strategies in response to climate risks and shocks, including growing early maturing varieties, dry planting, conservation agriculture, value addition, tree planting, animal feed conservation, improving livestock breeds, water harvesting, and agroforestry. The main constraints to the adoption of these strategies are the high costs of the technologies involved and limited knowledge about these technologies.
- Off-farm services for supporting farmers in dealing with climate change and variability include weather advisories, the formation of producer organizations, and crop and livestock insurance. The provision of these services is hampered by a lack of information and inadequate financial and human resources.
- Governmental, non-governmental, faith-based, and private organizations support climate-change adaptation efforts by providing financial and human resources. These organizations boost farmers' resilience by supplying inputs and offering extension services to improve their technical know-how.
- A stronger framework for collaboration will enable stakeholders to engage more fully through a participatory forum.

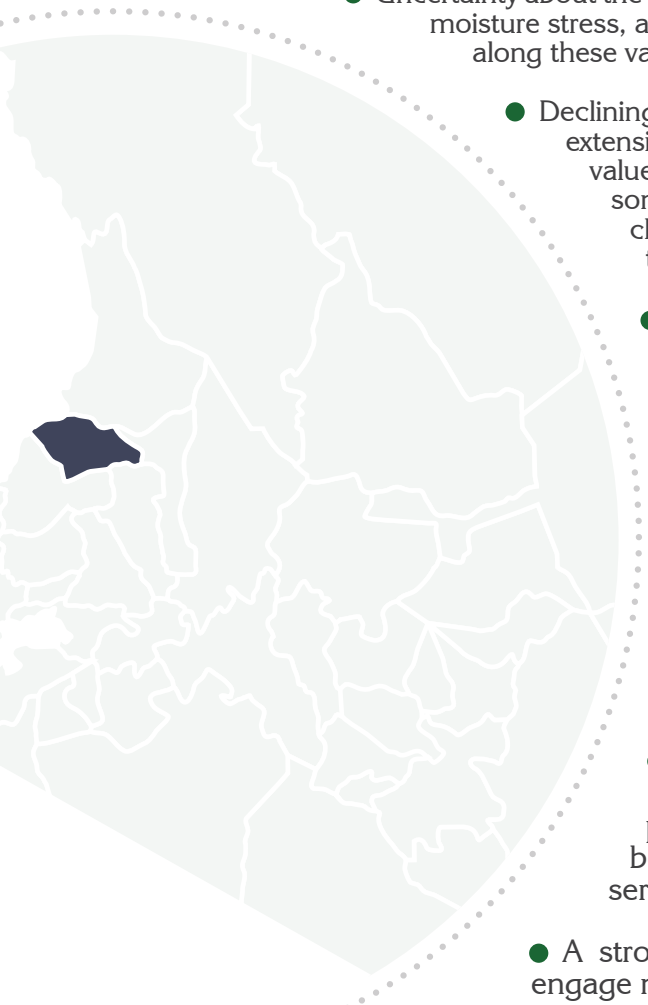

Figure 1: Map of Trans Nzoia County

Republic of Kenya

WORLD BANK GROUP

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List of Acronyms and Abbreviations

ADC	Agricultural Development Corporation
AI	Artificial Insemination
CDD	Consecutive Dry Days
CIDP	County Integrated Development Plan
CMIP5	Coupled Model Intercomparison Project Phase 5
IPCC [AR5]	International Panel on Climate Change [fifth Assessment Report]
KALRO	Kenya Agricultural and Livestock Research Organization
KEPHIS	Kenya Plant Health Inspectorate Service
KFA	Kenya Farmers' Association
KFS	Kenya Forest Service
KMD	Kenya Meteorological Department
K Sh	Kenyan Shilling
LGP	Length of the Growing Period
NARIGP	National Agricultural Rural Inclusive and Growth Project
NCPB	National Cereals and Produce Board
NCCRS	National Climate Change Response Strategy
NEMA	National Environmental Management Authority
P5D	Maximum 5-day precipitation
PELIS	Plantation Establishment Livelihood Improvement Scheme
RCPs	Representative Concentration Pathways

TransNzoia

Foreword

The mandate of the Ministry of Agriculture, Livestock, Fisheries and Co-operatives is to create an enabling environment for sustainable development of agriculture and co-operatives for economic development. This objective underpins our desire and commitment to transform Kenya into a newly industrializing, middle income country providing a high quality of life to all its citizens in a clean and secure environment as envisaged in our development blueprints, the Kenya Vision 2030, the Big Four Agenda and the Agricultural Sector Transformation and Growth Strategy (ASTSG 2019 – 2029). The sector remains high on the national development agenda in terms of food and nutrition security, income generation, employment creation, saving and investment mobilization and export earnings. To realize the country's aspirations of food and nutrition security, the Government through this Ministry is implementing the National Agricultural and Rural Inclusive Growth Project (NARIGP) with the support of the World Bank. The development objective of the project is to increase the agricultural productivity and profitability of targeted rural communities in 21 counties and in the event of an eligible crisis or emergency, provide an immediate and effective response.

The agriculture sector is however, highly vulnerable to the impacts of climate change and extreme weather events. Responses that would enable the country to cope with these risks are outlined in the Kenya Climate-Smart Agriculture (CSA) Strategy and in the commitments of the Kenya Nationally Determined Contributions (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC). In 2010, the Government developed the National Climate Change Response Strategy (NCCRS) which recognized the impacts of climate change on the country's development. This was followed by the development of the National Climate Change Action Plan in 2012. The focus of these initiatives include the development of county-level climate risk profiles to mainstream climate change perspectives in programs and development plans at county level. The Ministry has developed county climate risk profiles in 31 counties and NARIGP is supporting the development of profiles for an additional 14 counties. The purpose of the profiles is to inform county governments and stakeholders on the climate change risks and provide opportunities for integration into respective county development plans and processes.

This climate risk profiles study will be used as a basis to climate proof projects or any other developments in fourteen counties (Samburu, Turkana, Kitui, Narok, Kirinyaga, Kiambu, Muranga, Bungoma, Trans Nzoia, Nandi, Vihiga, Kisii, Nyamira and Migori). The study provides information on current and possible future climate scenarios, climate-related vulnerabilities and risks for key major agricultural value chains, policy landscape and the institutional capacity to deliver adaptation programs. Each profile presents adaptation and risk reduction options that can transform and reorient agricultural systems in the counties to increase productivity, enhance smallholder farmers' resilience and mitigate against climate change.

Finally, I call upon all stakeholders for their cooperation and support for adoption of CSA production practices that maximize the triple wins: increases productivity, enhanced resilience and reduced greenhouse gas (GHG) emissions. Through the adoption of new technologies and improved practices, we will realize the desired goal of Kenya being a food and nutrition secure country, fostering socio-economic development and improved livelihoods of Kenyans.

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Principal Secretary

State Department for Crops Development and Agricultural Research

1. Introduction

Climate change is becoming one of the most serious challenges to Kenya. The country is susceptible to climate-related events, and projections indicate that climate impacts will continue to affect Kenya in the future. In many areas, extreme and variable weather is now the norm. Rainfall is irregular and unpredictable; some regions experience frequent droughts during the long rainy season or severe floods during the short rains. Arid and semi-arid areas are especially vulnerable to these extreme changes, putting the lives and socioeconomic activities of millions of households at risk.

The Kenya Vision 2030 is a national blueprint that seeks to transform Kenya into a newly middle-income country which provides a high quality of life, in a clean and secure environment, to all its citizens by 2030. The agricultural sector is a key contributor to the projected annual national economic growth. However, agriculture has been constrained by inadequate access to quality inputs, marketing inefficiencies, a non-conducive investment environment, declining soil fertility, low mechanization, land fragmentation, and most significantly, climate change.

In 2010, Kenya developed a National Climate Change Response Strategy (NCCRS) that recognized the importance of climate change impacts on the country's development. This was followed in 2012 by the National Climate Change Action Plan, which provided a means to implement the NCCRS and highlighted agricultural adaptation priorities. These initiatives are focused on the national level, and climate change considerations still need to be mainstreamed in county-level policies, programs, and development plans. Locally relevant, integrated adaptation responses with the active involvement of local stakeholders are necessary to achieve this goal.

Through the Ministry of Agriculture, the Government of Kenya (GoK) is implementing the National Agricultural and Rural Inclusive Growth Project (NARIGP) with support from the World Bank. The project's objective is to increase the agricultural productivity and profitability of targeted rural communities in selected counties. To address the climate change risks and vulnerabilities that negatively impact agricultural production, the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) completed a climate risk assessment in 14 counties supported by NARIGP. The aims of the assessment are to provide information about the current climate and possible future climate scenarios, to pinpoint climate-related vulnerabilities and risks for major agricultural value chains and specific groups of people involved in agriculture, to identify adaptation options that address climate risks and vulnerabilities, and to assess the institutional capacity to deliver adaptation programs.

This climate risk profile seeks to inform county governments and stakeholders about climate change risks and opportunities for agriculture so they can integrate these perspectives into county development. This report will help county governments and stakeholders integrate climate change risks and opportunities for local agriculture into county development plans.

The Alliance implemented the assessment through a set of interrelated stages (Figure 2). It first initiated a desk review of the conceptual and analytical context of climate change risks at the national and county levels. Efforts were made to involve a wide range of institutions that have worked on climate change at national and regional levels. The team drew from globally available data sources like the Kenya Open Data Portal, from county development plans, and from relevant government departments, such as the Department of Resource Surveys and Remote Sensing, the Kenya Meteorological Department, and the Drought Monitoring Center. We also collected data through focus group discussions, interviews with carefully selected key informants, observation, climate modelling, and three days of sub-national stakeholder workshops. The final reports were then presented and validated by national and county-level stakeholders.

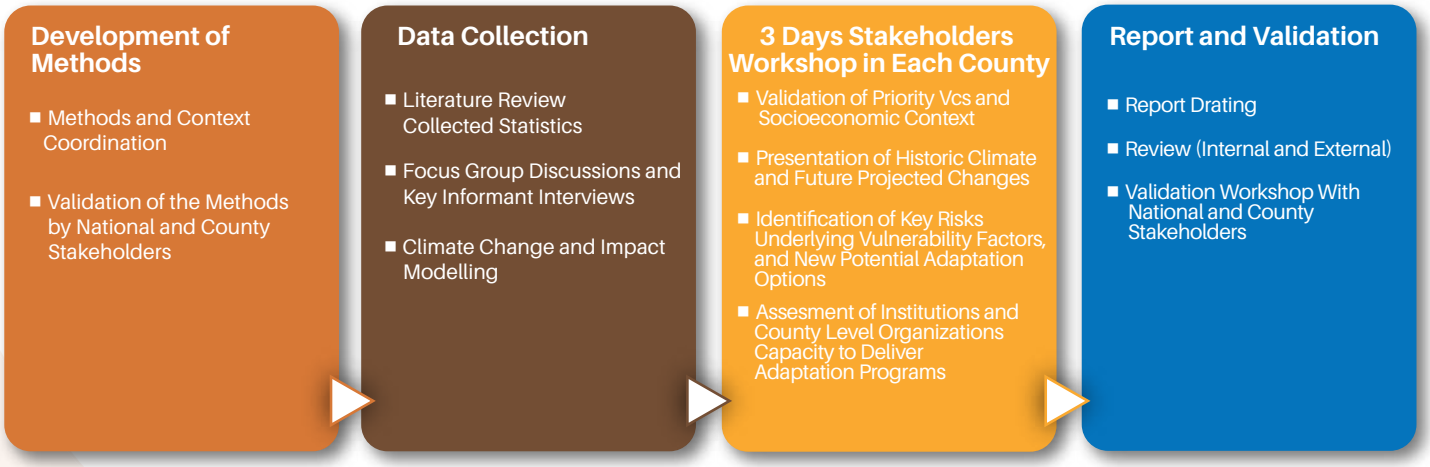


Figure 2 : Stages in developing a climate risk profile

This document presents the climate risk profile for Trans Nzoia County. It is organized into six main sections, each reflecting an essential analytical step towards understanding current and potential adaptation options in key local agricultural value chain commodities. The climate risk profile first offers an overview of the agricultural commodities key to food security and livelihoods in Trans Nzoia County, and then lists major challenges to agricultural sector development in the county. In the second section, it identifies the main climate hazards, based on an analysis of historical climate data and climate projections. These include scientific assessments of climate indicators for dry spells, extreme rainfall, moisture stress, and heat stress, among others. Third, this report continues with an analysis of vulnerabilities and risks posed by these climactic hazards to the identified value chains. Based on these vulnerabilities, the fourth section discusses current and potential on-farm adaptation options and off-farm services. In the fifth section, this climate risk profile also provides snapshots of the enabling policy, institutional, and governance contexts for the adoption of resilience-building strategies. Finally, the sixth section presents pathways for strengthening institutional capacity to address climate risks.

2. County Context

Trans Nzoia County covers an area of 2,495 km2. The county borders Uasin Gishu and Elgeyo Marakwet Counties to the southeast, Bungoma and Kakamega Counties to the south, West Pokot County to the east, and the Republic of Uganda to the west. Trans Nzoia County lies between latitudes 00° 52´ and 01° 18´ north of the equator and longitudes 34° 38´ and 35° 23´ east of the prime meridian.

2.1 The Economic Relevance of Farming

Agriculture is the mainstay of Trans Nzoia County. The vast majority of the county's population is involved in commercial and subsistence farming and livestock rearing. Most residents practice mixed farming involving both crop production and animal rearing. Trans Nzoia County is endowed with good arable land and favorable weather, both conducive to agricultural production. Farmers in Trans Nzoia County are engaged in the production of food crops, horticultural crops, and cash crops. The main crops grown are maize, beans, Irish potatoes, wheat, barley, finger millet, sorghum, and sweet potatoes (Table 1). Maize and beans account for 70% of the estimated income from crops (ASDSP, 2014). Food crop surpluses such as maize and beans are sold to traders and consumers in neighboring counties and beyond. Horticultural crops include bananas, bulb onions, cabbages, kales, oranges, and tomatoes. The major cash crops are coffee, sugarcane, and tea. The livestock reared in the county includes cattle for dairy and beef, poultry, goats, sheep, pigs, rabbits, and donkeys (Table 2). Apiculture is also practiced, although it is not well developed.

Table 1: Crop production in Trans Nzoia County (in order of size of planted area)

Crop	Planted area (ha)	Expected output (tons)	Sub-county
Maize	105,890	469,755	Saboti, Kiminini, Endebess, Cherang'anyi, Kwanza
Beans	25,500	8,614	Saboti, Kiminini, Endebess, Cherang'anyi, Kwanza
Irish potatoes	1,150	1,523	Saboti, Cherang'anyi
Kale	310	12,400	Cherang'anyi
Tomatoes	150	9,000	Cherang'anyi
Cabbage	150	3.750	Cherang'anyi

Source: County Government of Trans Nzoia. 2020a

Table 2: Livestock populations in Trans Nzoia County

Livestock Species	Number
Dairy cattle	197,332
Beef cattle	10,300
Sheep	137,461
Goats	37,799
Pigs	5,807
Rabbits	5,000
Indigenous chickens	693,730

Source: County Government of Trans Nzoia. 2020b

The agricultural sector directly employs over 80% of the rural population. Men, women, and youths aged 15-35 years are active in the agricultural sector. Women and youths are mainly engaged in on-farm activities such as the production and harvesting of agricultural produce. Men are involved in the commercialization and marketing of agricultural produce, and youths mainly participate in transporting the produce to markets and selling it. Women provide more family and hired labor in crop production than men and youths (ASDSP, 2014). As regards livestock production, youths contributed the largest share of labor, while women were responsible for the smallest share.

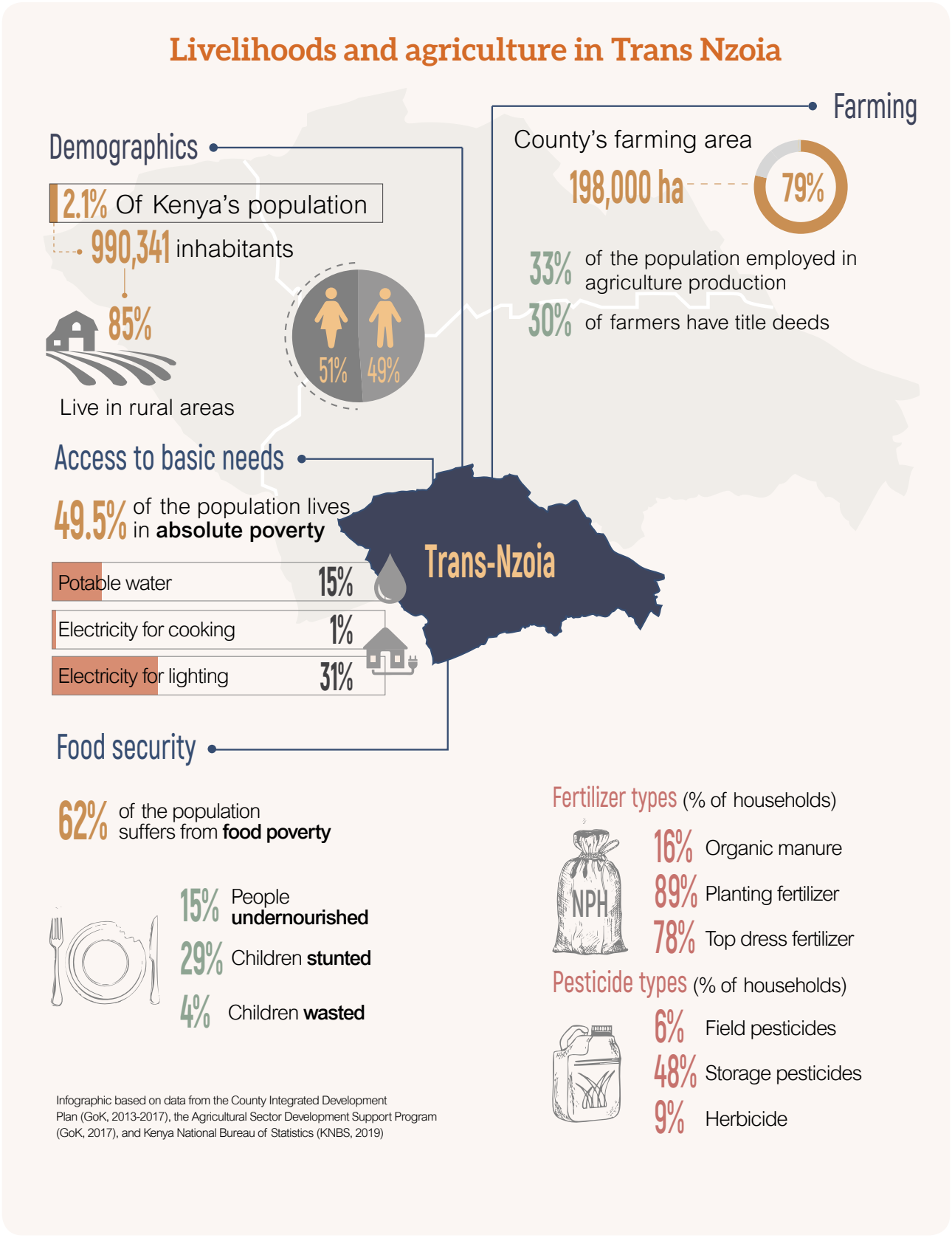


Figure 3: Agriculture and livelihoods in Trans Nzoia County

2.2 People and Livelihoods

According to the 2019 census, the total population of Trans Nzoia County is 990,341 persons, of whom 489,107 were male, while 501,206 were female KNBSa, 2019). This represents a 21% increase over the 2009 population and housing census, which enumerated a total of 818,757 persons in the county, of whom 407,172 were male and 411,585 were female. Youths ages 15-35 years represent about 79% of the county population. Trans Nzoia County contains 223,808 households with an average household size of 4 persons and a population density of 343 persons per km^2 (KNBSa, 2019). The county has two main urban centers, namely Kitale and Kiminini, which account for 15% of the total county population, while 85% of the population resides in the rural areas.

Trans Nzoia County has an absolute poverty level of 50%, compared to the national average of approximately 36% (Figure 3). Contrarily 41% of the population live below the poverty line (US$ 1.90 a day) In Trans Nzoia County, 65% of the population has access to potable water (County Department of Water, personal communication). Around 20% of the county's households have access to piped water as opposed to about 34% of households nationally (KNBSb, 2019).

The literacy rate in Trans Nzoia County is almost 80%, as compared to the national literacy rate of about 82% (KNBSb, 2019). Disaggregated by gender, men's literacy rate stands at 81%, while that of women is 79% of the population. Approximately 38% of households use electricity as their main source of lighting and fuel, as compared to 50% at the national level, and 0.6% of the households in Trans Nzoia use electricity for cooking, as compared to 0.9% at the national level (KNBSb, 2019).

The prevalence of undernourishment in Trans Nzoia County stands at just over 15%, which is above the national average of approximately 11%. The rate of stunting is 29%, as compared to the national level of 26%. The rate of wasting in Trans Nzoia County is 3.9%, which is almost on a par with the national average of 4.2%. Among the county's households, in recent years, 63% have lacked sufficient food to meet their household needs (ASDSP, 2014). The peak food scarcity period in Trans Nzoia County occurs between May and August, and at 52%, higher proportions of female-headed households are food insecure than of male-headed households at 38% (ASDSP, 2014). Children had three meals a day, while men and women ate two meals (ASDSP, 2014).

The populace in Trans Nzoia takes part in on-farm, non-farm, and off-farm activities. In Trans Nzoia County, 63% of household heads were engaged in crop growing or livestock rearing as their primary occupation, while 13% held formal salaried employment in both government and non-government positions. About 8.3% were self-employed. Most of the households (80%) have only one source of income (ASDSP 2014).

2.3 Agricultural Activities

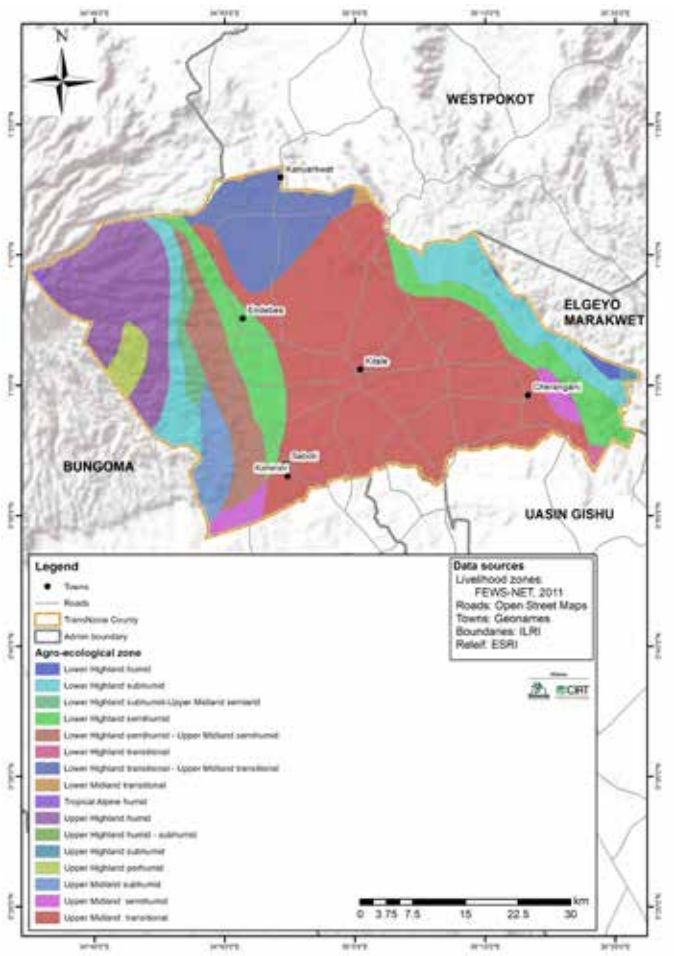


Figure 4: Map of agroecological zones in Trans Nzoia County

Out of 47 counties, Trans Nzoia is ranked the 37th largest in terms of land size. The major land uses in Trans Nzoia County are agricultural activities – farming crops and keeping livestock – and forestry. Arable land covers 1980 km^2, representing 79% of the total land area, while non-arable land accounts for 21%; there is no water mass. The non-arable land includes the Mt. Elgon forest, which measures 169 km2. Trans Nzoia County is endowed with two forests that are found on the two water towers, namely Mt. Elgon and the Cherang'anyi Hills.

Trans Nzoia County is divided into three major agroecological zones (Figure 4). These include the Upper Highlands, Upper Midlands, and Lower Highlands (Jaetzold et al. 2010). The Upper Highland Zone lies between the altitudes of 2,400 and 4,313 m. It encompasses hills and slopes of Mt. Elgon, parts of the Cherang'any Hills, and the boundary hills towards West Pokot County. This zone comprises about 16% of the county's land area. The Lower Highland Zone lies within altitudes ranging from 1,800 to 2,400 m. It accounts for 34% of the total land area of Trans Nzoia County and contains slopes of Mt. Elgon and parts of the Cherang'any Hills. The Upper Midland Zone occupies 50% of the total land area of Trans Nzoia County. It

lies between 1,700 and 2,000 m above sea level with mean annual rainfall of 900 mm – 1,400 mm. Both the Lower Highland and Upper Midland Zones hold strong promise for farming activities including horticulture and the cultivation of maize, wheat, sunflowers, coffee, and barley, as well as livestock activities such as the rearing of cattle and sheep. The Lower Highland Zone, in addition, has good potential for the cultivation of tea and pyrethrum.

A large proportion of the land in Trans Nzoia County is under private ownership as either leasehold or freehold. Freehold gives the holder absolute ownership of the land for life, while leasehold applies to a specific period subject to payment of a fee. The average farm size in Trans Nzoia County is about 4.7 hectares. Sizes range approximately from 0.8 hectares for a small-scale farm to 22.6 hectares for a large-scale farm. Since land factors into production, landowners with title deeds enjoy opportunities to borrow or undertake investments to boost agricultural productivity, using land as collateral. Female-headed households allocated more of their land to subsistence crops, while men and youths allocated most of their land for commercial crops (ASDSP, 2014).

The use of agricultural inputs depends on the agricultural enterprise and the purpose of growing the crop. Input use is prevalent for crops grown for commercial purposes, while crops grown for subsistence recorded low input use. For instance, farmers who grew cabbage, bulb onions, indigenous vegetables, maize, and sunflowers use improved seed varieties, while those who grew beans, sweet potatoes, finger millet, and sorghum relied on recycled or local seed (ASDSP, 2014). About 90% of households use fertilizers for annual crops. The use of pesticides and herbicides, on the other hand, is relatively low; less than 10% of households record the use of these inputs. Input use is hindered by high prices coupled with meagre incomes. In livestock production, 56% of households use de-wormers, 52% use acaricides, and 50% use salt; these are the most-used inputs. Even though the use of inputs is associated with increased productivity, it can also cause environmental pollution and soil acidification. Perennial use of basal fertilizers has been linked to increased acidity levels in the soils. Heavy input usage has also resulted in the pollution of water sources. Trans Nzoia County has utilized only one of 14 potential irrigation schemes, covering 200 hectares and serving 450 households (County Government of Trans Nzoia, 2018). Major seed companies in the county use sprinkler irrigation during their off-season for seed maize on 400 hectares of land, for tomatoes over a span of 200 hectares, and for vegetables across 100 hectares.

2.4 Agricultural Value Chain Commodities

For the development of this profile, we compiled a list of the major agricultural value chain commodities (VCCs) in Trans Nzoia County that are prioritized by the County Integrated Development Plan (CIDP), development programs such as the NARIGP, the Agricultural Sector Development Support Programme (ASDSP), and government institutions such as the Kenya Agricultural and Livestock Research Organization (KALRO). We created this list using the following indicators: productivity characteristics, including harvested area, production, and production variations in the past five years; economic value in Kenyan shillings (KSh); and nutritional characteristics like dietary energy consumption (Kcal/capita/day) and protein, iron, zinc, and vitamin A content. We then presented this list to stakeholders during a 3- day workshop for in-depth analysis and selection. The selection process was further honed by using the following set of criteria upon which the stakeholders first agreed: resilience to current and future climate change impacts, rated on a scale from low to high; the percentage of population involved in the value chain (%); and the involvement in the value chain of economically and socially vulnerable groups, such as poor people, women, and youths, on a scale from low to high. Each value chain was assessed against each criterion, and the value chains that engaged the highest percentage of the population as well as poor people, women, and youths were selected. The four VCCs that were selected for this report are dairy cow, indigenous chickens, maize, and beans (Figure 5).

2.4.1 Maize

Maize is a key staple crop grown for both subsistence and commercial purposes in Trans Nzoia County. Maize is cultivated in all the agroecological zones and across the length and breadth of the county. According to the county directorate of agriculture, in 2020, the area under maize production was 105,890 hectares with an expected output of 469,755 tonnes (Table 1). Over 80% of the population is engaged in the production of maize contributing to food security and nutrition. Historically, in Trans Nzoia County, maize is planted once per year during the long rains, but given the increasingly unpredictable weather occasioned by changes in rainfall patterns, growing maize twice a year is gaining in popularity. Rains are now experienced in October, November, and December, which were hitherto regarded as months receiving insufficient rain for maize production.

In terms of actors involved in the maize value chain, input suppliers vary from large- to small-scale. Large-scale input suppliers include companies like the Kenya Seed Company, Western Seed Company, Agri Seed Company (SEEDCO), and the Agricultural Development Corporation (ADC), while the small-scale input suppliers consist of the agro-vets retailing all over the county. The level of engagement in input supply is high for men, very low for women, and low for the youth. Maize farmers in Trans Nzoia include large-, medium-, and small-scale operations as determined by the size of land under production. The engagement of women and youths in on-farm production is high,

while for men it is low. Processors in the maize value chain also range from large- to small-scale. Examples of the large processors include Kitale Industries Limited and Unga Group Limited; Simba is a medium-sized actor; and small-scale processors include the local *posho* mills spread across the county's villages and market centers. At the post-harvest stage, the level of participation by women and youths at the farm level is high, while for the men it is low.

Maize markets embrace large-, medium-, and small-scale output markets. The large-scale markets include the National Cereals and Produce Board (NCPB), Unga Group Limited, and Cargill Limited. Medium-scale markets include maize traders, while small-scale traders are found in rural and urban market centers throughout the county. Men have high levels of engagement in the output market, while for women and youths, involvement is low. There are structured markets in the maize value chain which consist of the millers and government bodies such as the NCPB. Unlike local traders and markets, these structured markets provide farmers with an outlet to sell their produce at stable prices. Non-structured markets comprise retail and wholesale traders who sell maize in trading centers. Maize farmers in Trans Nzoia are price-takers because they are in no position to bargain. Prices are determined by the market forces of supply and demand. Farmers plant and harvest at the same time, causing market gluts, so their produce commands low prices. This situation is exacerbated by cheap maize imports from neighboring countries. Only a scant 5% of farmers had contractual arrangements (ASDSP, 2014).

2.4.2 Beans

In terms of acreage, beans rank as the second most-grown crop after maize in Trans Nzoia County. Beans are grown both for subsistence and for commercial purposes. They are commonly intercropped with maize or grown as a monocrop. According to the county's directorate of agriculture, in 2020, the projected area under beans was 25,500 hectares with an expected output of 8,614 tonnes. At the household level, beans contribute to food security by providing a low-cost high-value plant protein component. Beans are grown from March to May by some farmers, while others prefer to cultivate beans from October to December as a stand-alone crop. Unlike the short rainy season, the long rainy season is characterized by heavy excess rainfall that is not conducive to bean production. Approximately 61-80% of the population is engaged in the beans value chain.

In terms of the actors engaged in the value chain, input suppliers are small-scale and mainly consist of agro-vets in rural and urban centers. Both medium- and small-scale farmers participate in bean production. Medium-scale farmers produce for commercialization purposes, while small-scale growers do so for subsistence. Women and youths are highly engaged in on-farm production, while men's involvement is low. Beans are processed at a small scale in Trans Nzoia County, mainly involving threshing, winnowing, and sorting. Women and youths are highly engaged in processing, while men's participation is minimal. In the output market, the major actors are medium- and small-scale. The small-scale actors comprise women who sell beans to customers as food or seed, while the medium-sized traders are mostly men who aggregate the beans to be sold to markets further afield. There are no certification standards in bean marketing in Trans Nzoia County. Bean prices are determined by market demand and supply. Prices are high when there is bean scarcity in the market. There are no subsidies or tariffs to control the prices of beans.

2.4.3 Dairy Cow

Dairy cattle farming is practiced throughout Trans Nzoia County. Most farmers combine dairy farming with crop farming in a mixed farming system. In 2019, there were 197,332 heads of dairy cattle in Trans Nzoia County that produced a total of 185,197,315 kgs of milk (County Department of Livestock, 2020). On average, each animal generates 8.5 liters per day through the lactation period. The main dairy breeds in Trans Nzoia County include Friesian, Ayrshire, Guernsey, Jersey, crosses, and several indigenous breeds. About 61-80% of the population is engaged in dairy value chain. Dairy products contribute to household food and nutrition security by providing a protein source as well as other elements.

A wide array of actors is engaged in the dairy value chain, including large-, medium-, and small-scale input suppliers. Large-scale suppliers include animal feed manufacturers, such as Kitale Industries Limited and Unga Group Limited, which produce concentrates from milling by-products. The Kenya Farmers' Association (KFA) is a farmers' organization that acquires inputs for farmers at a subsidized rate. Breeders and research institutions include larger institutions like the ADC and KALRO, as well as small-scale actors like the agro-dealers across rural and urban centers. Research institutions, meanwhile, explore technology interventions and the improvement of breeds. Both men and youths are highly engaged in input supply, while women's participation is low. Large-, medium-, and small-scale farmers are involved in the on-farm production of cow milk. Most dairy farmers are small-scale, rearing between 1 and 5 animals. Large-scale dairy farms encompass institutional organizations such as the ADC and individual farmers who have large farms. Men, women, and youths are highly involved in on-farm production of cow milk. Processors in the dairy value chain consist of large-scale actors such as New Kenya Cooperative Creameries and Brookside, medium-scale actors such as producer organizations, and small-scale farmers. Men and youths are highly involved in dairy milk processing while women's engagement is medium. Milk markets include large-scale actors such as supermarkets, medium-scale

actors such as milk bars in urban centers, and small-scale milk hawkers in markets, plus farmers selling at farm gates. Youths are highly engaged in the output market through activities such as transportation and informal selling of milk in local markets.

2.4.4 Indigenous Chickens

Rearing indigenous chickens is a low-capital enterprise that attracts many farmers. Indigenous chickens are reared by almost all the farming households in Trans Nzoia County that practice mixed cropping and livestock rearing. They are kept for both meat and egg production at subsistence and commercial levels. There are an estimated 693,730 birds in the county, producing about 208,119 kgs of meat (County Government of Trans Nzoia. 2020b). Around 80-100% of the population participates in the value chain.

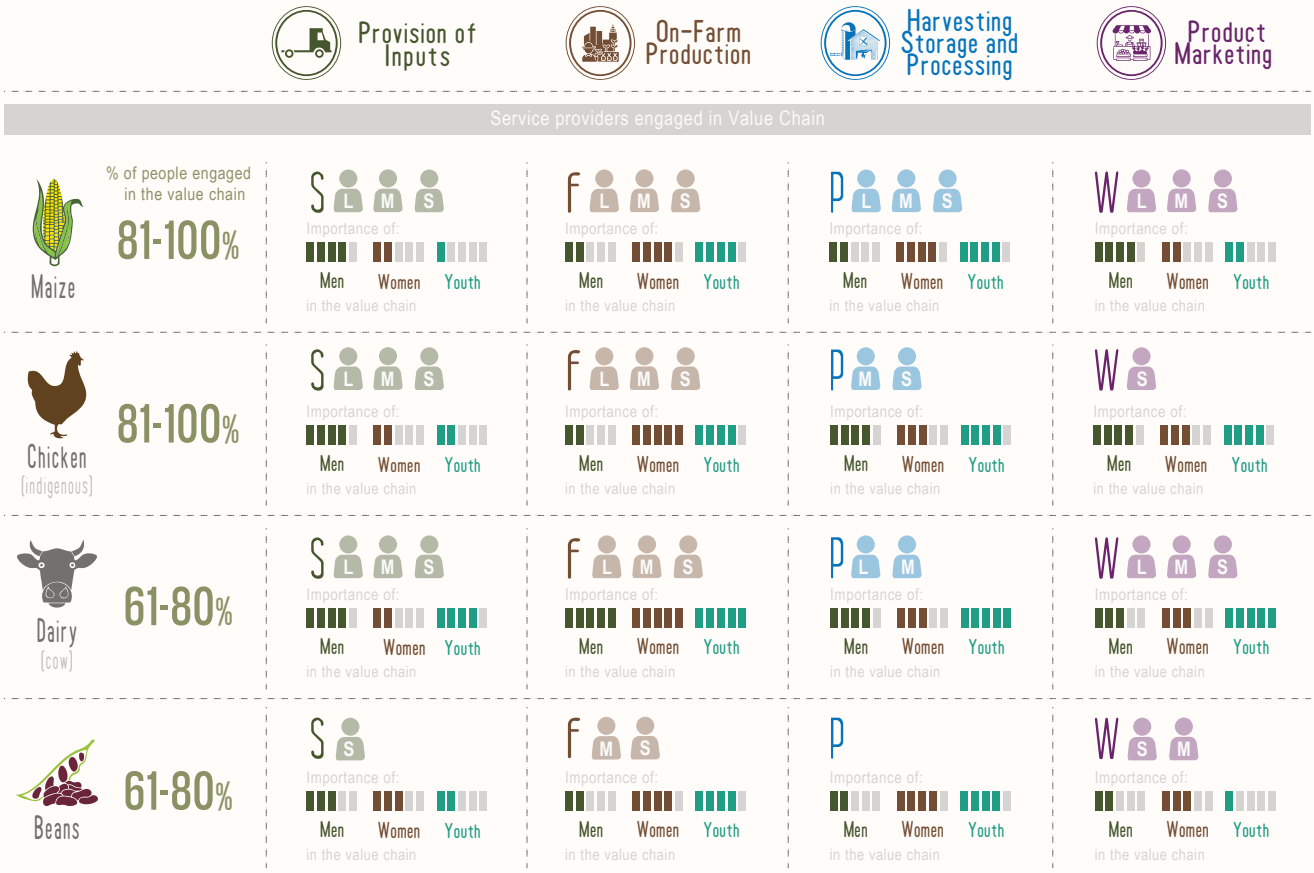
Input suppliers vary from large-scale actors such as the animal feed manufacturers Kitale Industries Limited and Unga Group Limited to small-scale vendors such as rural and urban agro-vets. Men are highly involved at the input supply stage, while youth engagement is middling, and women's participation is low. Farmers involved in indigenous chicken rearing range from large-scale operations with thousands of birds to small-scale actors with just a few birds. Women and youths are highly involved in on-farm production of indigenous chickens, while the engagement of men is low. Women are the primary owners of chickens in Trans Nzoia County; they feed the birds and carry out other routine management practices. Processors are mainly medium-scale actors, including slaughterhouses and restaurants, while small-scale actors concentrate in local markets and include farmers. Chickens are slaughtered in slaughter slabs, after which they are sold to consumers, restaurants, and supermarkets. Men and youths are highly involved in processing, while women's participation is middling. Youths are involved in slaughtering and packaging the chickens. In the output market, wholesalers and retailers are largely small-scale actors, and upcoming producer organizations represent medium-scale actors. The output market is dominated by men and youths, with women playing a secondary role. There are no certification standards in the indigenous chicken market, and prices are dictated by market forces of supply and demand dependent upon the availability of chicken in the market.

2.5 Agricultural Sector Challenges

As Kenya's grain basket, Trans Nzoia County faces many challenges. It has experienced declining land productivity over the years caused by acidification due to continuous usage of basal fertilizers such as diammonium phosphate. This situation has resulted in reduced output of the traditional crops grown in the county such as maize and beans. Extension services lack sufficient capacity, and changes in institutional policies have rendered extension services more demand-driven and hampered their provision. Historically, extension officers visited farmers without invitation, but now farmers must invite the extension agents to visit them, and this seldom happens, so productivity has declined. Weak extension linkages have led to low adoption rates of technologies, an issue further aggravated by their high cost and the dearth of financial resources available to farmers. The high cost of technologies and high input costs have contributed to high production costs. This problem has been compounded by inadequate access to affordable credit facilities, which has resulted in a vicious cycle wherein every planting season is characterized by delays in seed supplies and fertilizer shortages. The vagaries of the weather have worsened the situation as changes in seasonality, longer dry spells, and more excess rainfall have adversely affected agricultural production. Poor road infrastructure is also a factor driving increased losses among farmers, because they cannot deliver their produce to markets on time and inputs cannot be transported in a timely number. With regard to livestock production, theft of livestock both cattle and chicken has become rampant in the county and is a key socio-economic challenge to the growth of the livestock sector. Farmers have to contend with livestock thefts which act as a disincentive to the farmer.

Little or no value addition and inadequate storage and processing facilities have forced farmers to sell their raw produce. Value-added produce fetches higher prices than raw products. This scenario has resulted in lower prices paid to farmers since most of their produce has a short shelf-life, and therefore farmers become price takers.

Agricultural value chains in Trans Nzoia



Conventions

Service Providers: S Suppliers f Farmers P Processors W Wholesalers/ retailers

s small-scale m medium-scale l large-scale

ND: No data

Importance of women, youth men and women: 5 4 3 2 1 — 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high; 0 =non-exsistant; N/D = no data.

Figure 5: Characterization of selected agricultural value chains in Trans Nzoia County

3. Climate Change-Related Risks and Vulnerabilities

In generating this profile, we assessed past trends and future projections of precipitation and temperature, and computed several related hazards from these two variables. These hazards included extreme hydrological events including flash floods, droughts, moisture stress, heat stress, and the start and length of the growing seasons. We analyzed these hazards to evaluate climate change and variability in Trans Nzoia County. The growing season was defined as follows: the first, long rainy season is the 100-day wettest period from January to June, while the second, short rainy season is the 100-day wettest period from July to December (KMD, 2020).

We used Representative Concentration Pathway (RCP) 8.5, one of the four greenhouse gas concentration trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2014. Future climate projections were generated based on an ensemble of multiple Coupled Model Intercomparison Project (CMIP5) models (Taylor et al., 2012), using RCP 8.5 for two future periods, 2030 and 2050.[1]

To assess droughts and dry spells, we focused on the maximum number of consecutive dry days (CDD), defined as days receiving rainfall measuring less than 1mm (precipitation < 1 mm day-1). We determined heat stress by measuring the total number of days with maximum temperatures greater than or equal to 35°C (NT35). Growing days are the days during a season when average temperatures are greater than or equal to 5°C and precipitation exceeds half the potential evapotranspiration. The start of the growing season was determined by the occurrence of 5 consecutive growing days, while the length of the growing period (LGP) was determined as the total number of growing days.

For each season, heavy precipitation events were captured using the 5-day running average of rainfall, indicative of floods, and the 95th percentile of daily precipitation, indicative of extremely high rainfall over a short period of time that can lead to events like flash floods. For each pixel, we calculated the 95th percentile of daily precipitation distribution based on the 100 wettest days per season per year.

To assess the adequacy of rainfall and soil moisture to meet potential water requirements for agriculture, we focused on drought stress, represented by the number of consecutive days in each season where the ratio of actual to potential evapotranspiration falls below 0.5. This value was calculated for each pixel per season per year by evaluating the soil's water capacity and evapotranspiration in order to define the number of days that could undergo this level of stress.

3.1 Climate Change and Variability: Historic and Future Trends

Trans Nzoia County experiences two continuous growing seasons: the long and short rains. The driest months are December through February. The county receives a large amount of rainfall – up to 2,000 mm in the western region. Mean temperatures range from 12-25°C (Figures 6 and 7).

The rainfall trends in the past and in the future does not show significant changes for the long rainy season. However, for the short rainy season, rainfall will increase in the near future (2020-2040) and continue to do so by 2060 (Figure 8). The trends in temperature show an increase in the annual mean temperature for both seasons and for both projections (2020-2040 and 2041-2060) (Figure 9).

The number of CDDs serves as an effective measure of the extremely low precipitation and of the incidence of seasonal droughts. The number of CDDs in the long rainy season is expected to slightly increase from 3 to 8. In short rainy season, the number of CDDs is expected to lessen by up to 5 days. The maximum 5-day precipitation (P5D) serves as an indicator of flood risk and is projected to increase from 6 mm to 13 mm (Figure 11). In the second season, the maximum 5-day running average precipitation is expected to increase by 10-16 mm throughout Trans Nzoia County. These overall increases in the P5D indicate greater flood risk throughout the county. The 95th percentile of daily precipitation for a season serves as an indicator of heavy rainfall or very wet days. The 95th percentile of daily precipitation in the long rainy season will slightly increase by around 3 mm in the eastern and western regions, while in the short rainy season, it will increase by 10-16 mm throughout Trans Nzoia County. This indicator is linked with erosion risk.

There is no expected change in heat stress in Trans Nzoia County in either season, but moisture stress, which serves as an indicator of the available soil moisture for plants, is projected to increase by around 15 days in almost every region of the county during the long rainy season (Figure 10). On the other hand, moisture stress will decrease by up to 10 days in short rainy season. Higher values of moisture stress negatively affect the vegetative growth of crops during the growing season. An early start to the long rainy season is expected throughout the county, except in the western regions, where the season will be 20 days sshorter. This change in the start of the growing season will be replicated in the short rainy season with

1For historical precipitation and temperature trends, we used the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) and Climate Hazards Group Infrared Temperature with Stations (CHIRTS). For future climate projections we used an ensemble of downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor et al., 2012, Navarro-Racines et al 2020), specifically the MOHC_HADGEM2_ES, CESM1_CAM5, GFDL_CM3, MPI_ESM_LR, and MIROC_MIROC5 models

the number of days varying from 40 to 90 days. The LGP is estimated based on the period when climatic conditions are suitable for crop growth. A significant reduction in the length of the long and short rainy seasons is predicted; they may become 20-70 days shorter. A shorter LGP will have serious implications for farming because current varieties will not have sufficient time to meet plant growth requirements.

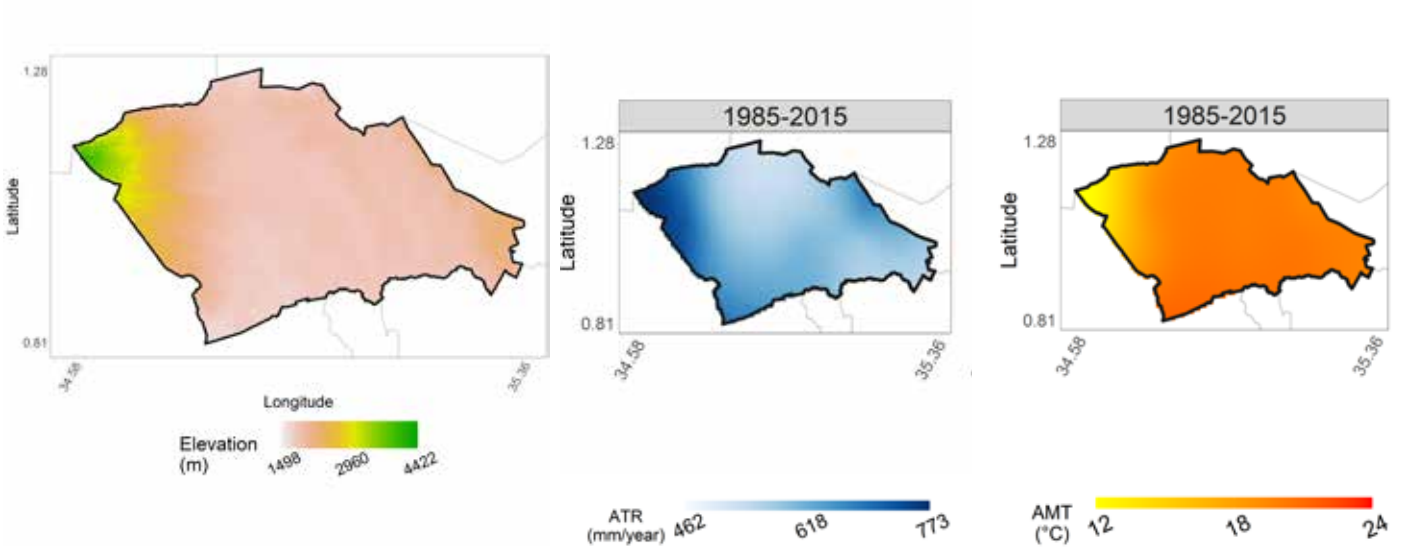


Figure 6: Elevation (left), historical (1985-2015) annual mean precipitation in mm (center), and historical (1985-2015) annual mean temperature in °C (right) for Trans Nzoia County for the long rainy season

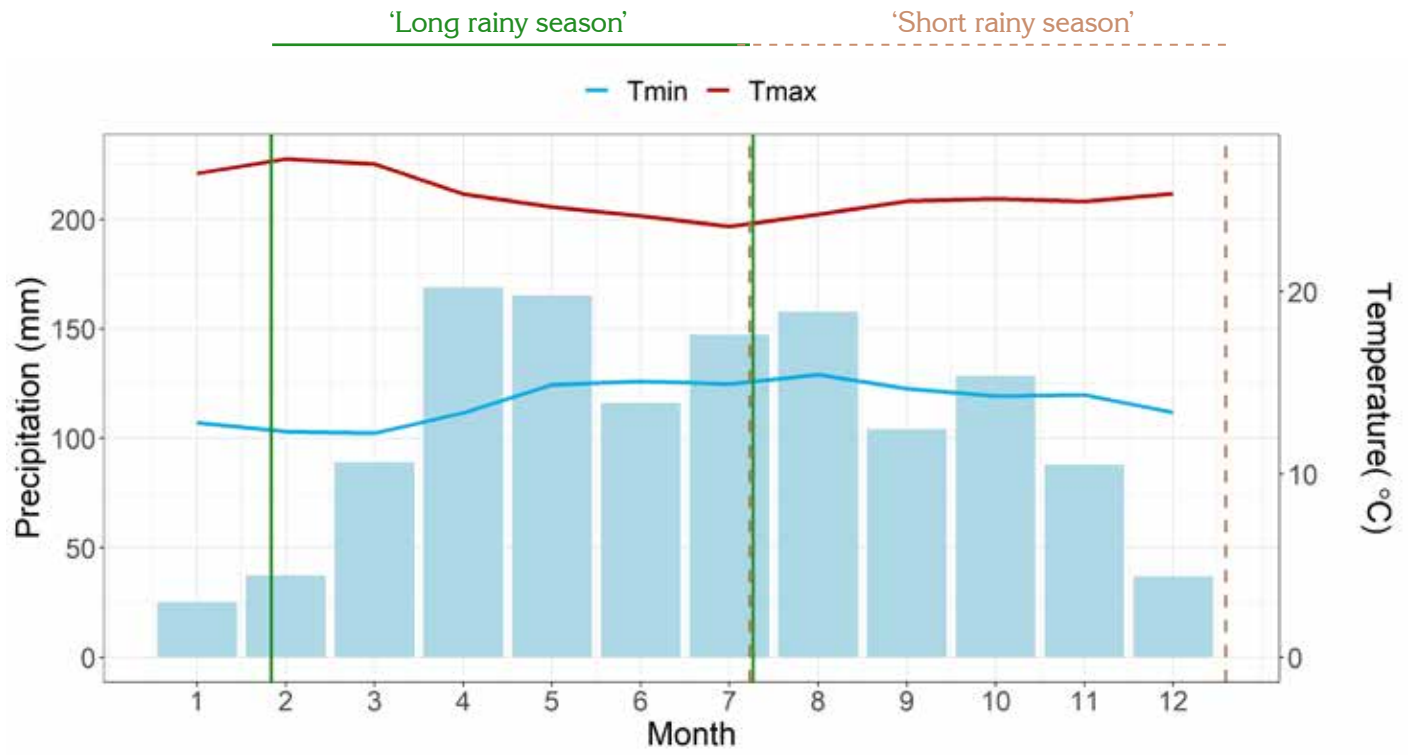


Figure 7: Average historical monthly mean temperature and precipitation over the last 30 years (1985-2015) for Trans Nzoia County. The long rainy season is the 100-day wettest period from January to June, while the second, short rainy season is the 100-day wettest period from July to December. Bars represent total monthly precipitation, whereas the red and blue lines represent maximum and minimum monthly mean temperatures, respectively.

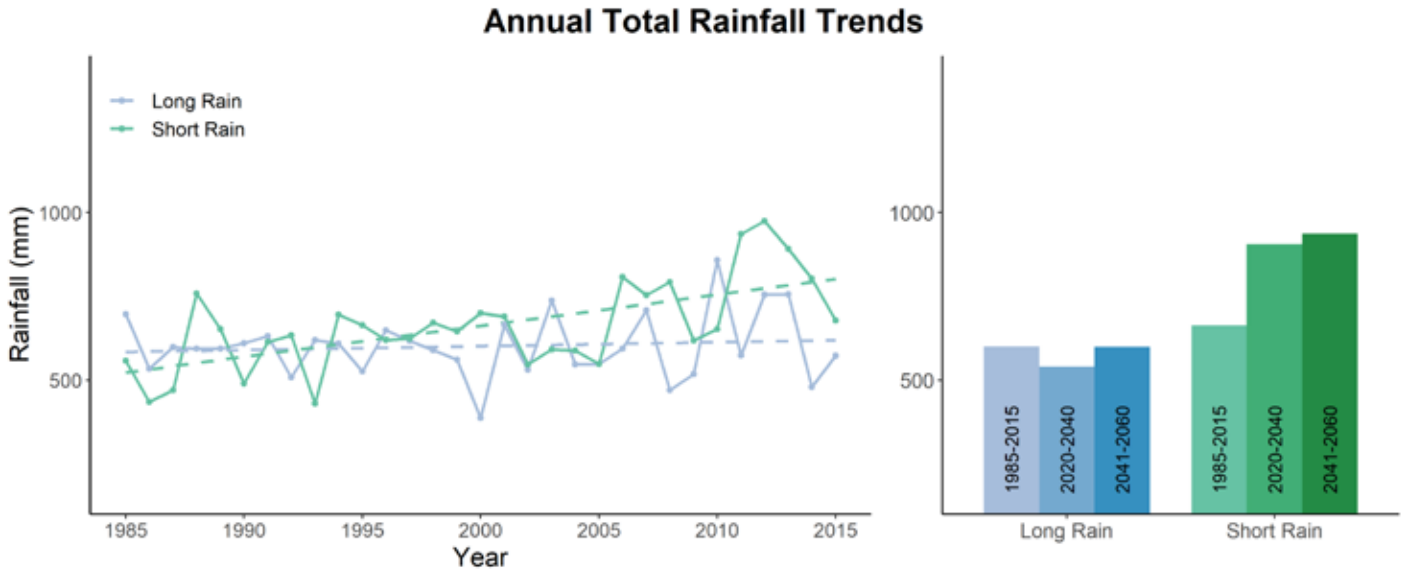


Figure 8: Historic (1985 - 2015) and future rainfall trends (2020-2041 and 2041-2060)

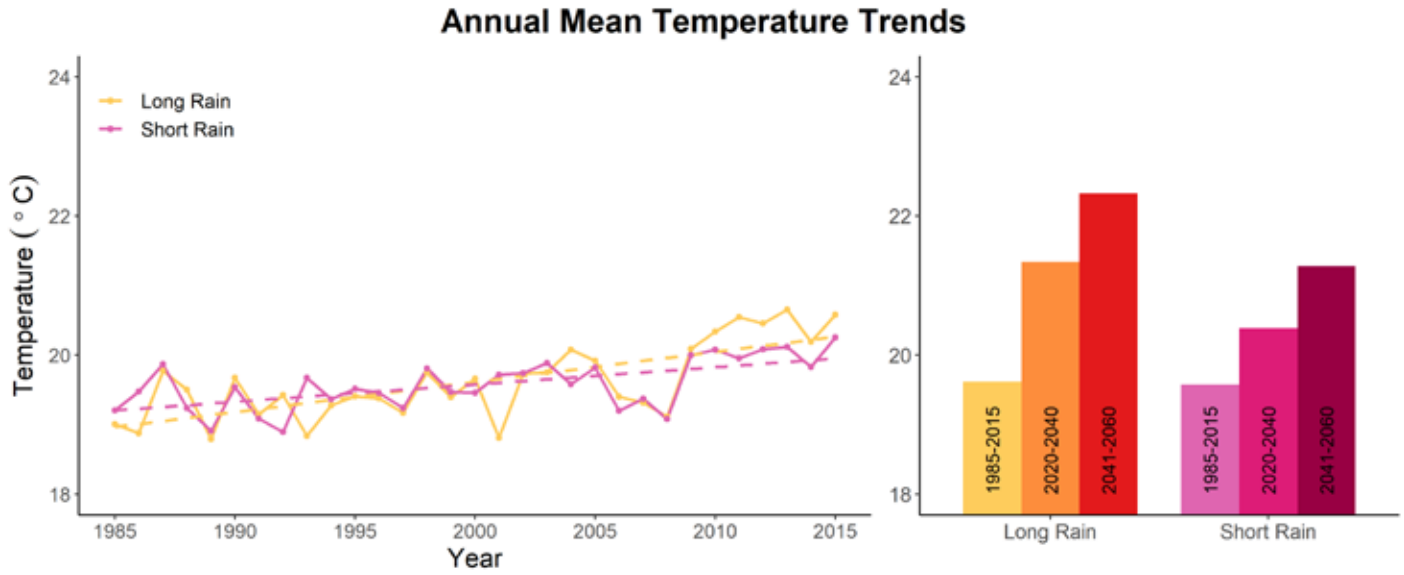


Figure 9: Historic (1985 - 2015) and future temperature trends (2020-2041 and 2041-2060)

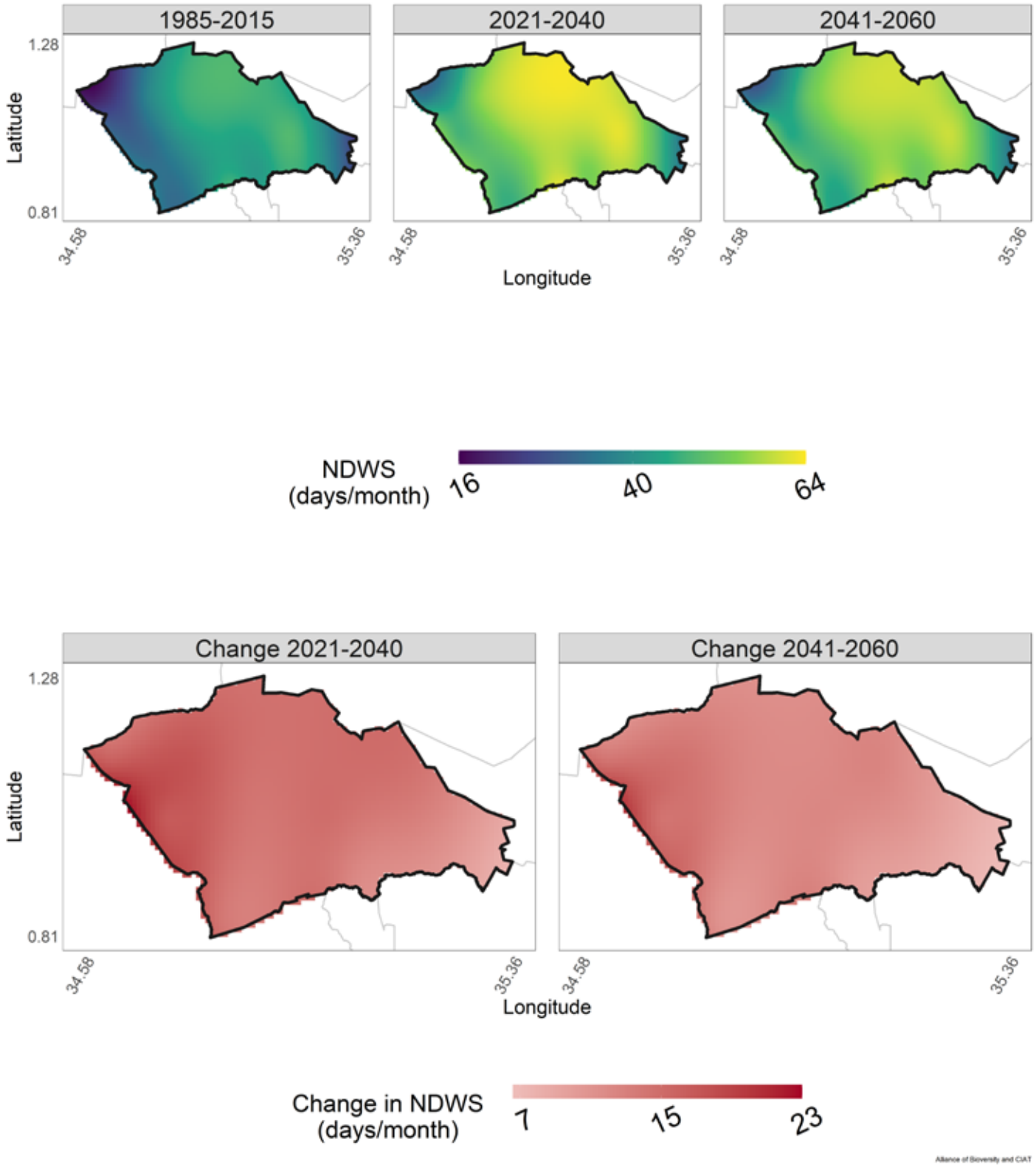


Figure 10: Average number of moisture stress days for the long rainy season: historical (left), future projected (center), and projected change (right)

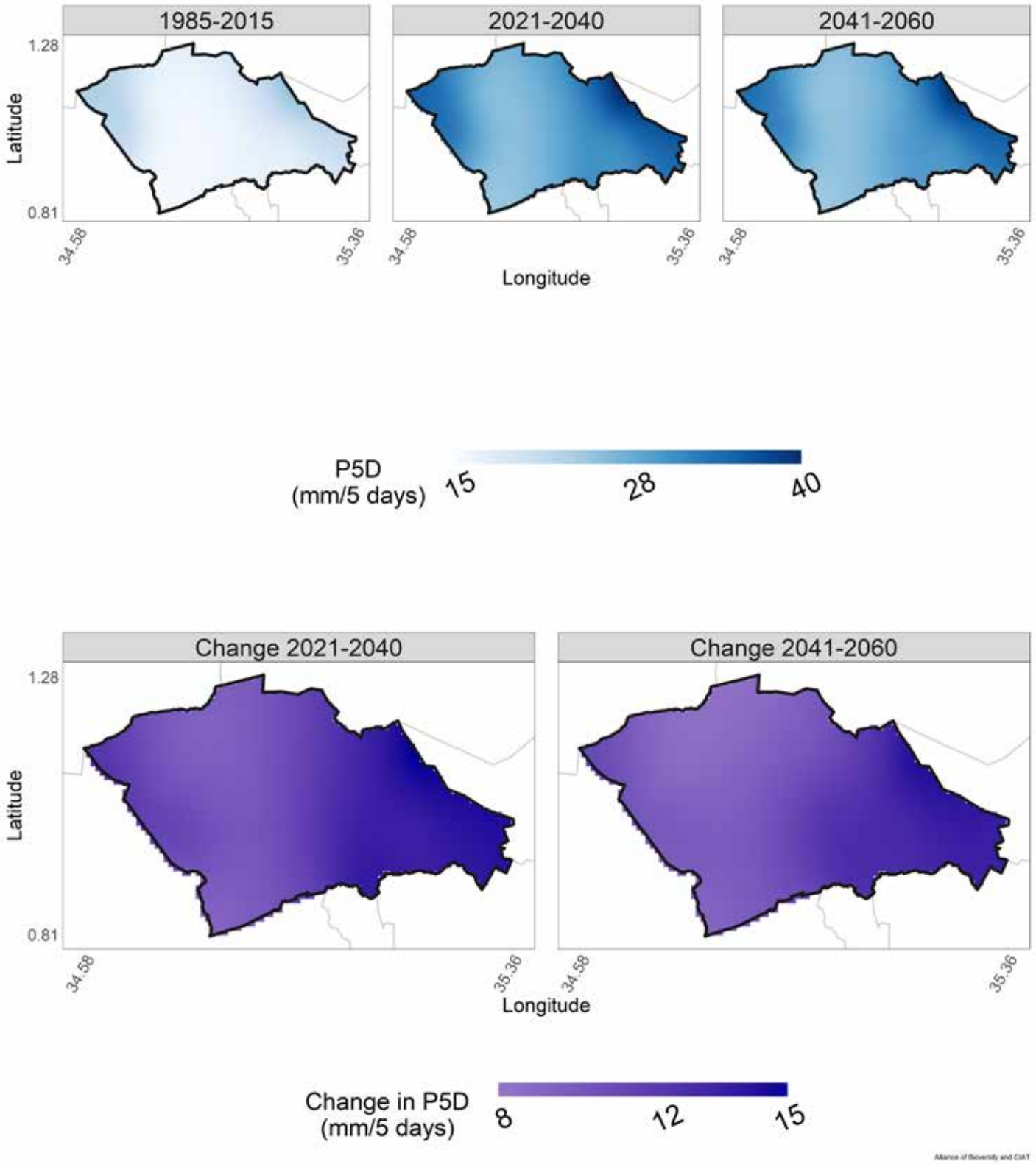


Figure 11: Average maximum 5 days running average precipitation for the short rainy season: historical (left), future projected (center), and projected change (right)

3.2 The Climate from Farmers' Perspectives

Farmers in Trans Nzoia County can attest to climate change as result of their recent experiences. They have noticed changes in the starting of the growing season, which has shifted from March to April or even later. Farmers have also reported years when the growing season has started before March, catching them unaware and unprepared. This variability has caused significant uncertainties about the acquisition of inputs such as seeds and fertilizers in preparation for planting. In addition, farmers reported instances of the rains disappearing mid-season. This has caused untold suffering to maize farmers who grow varieties that take 6 months to mature. Farmers have experienced an upsurge in pests like the fall armyworm, and they have attributed disease incidences hitherto unheard of in Trans Nzoia County to changes in the weather patterns. Farmers have also experienced additional occurrences of unusually heavy rainfall, which have led to flooding along the River Sabwani in Kwanza sub-county that displaced people, destroyed crops, and caused losses in livelihoods. Excess rainfall has resulted in total failure of some crops, such as beans. In the same vein, farmers have experienced increasing amounts of rainfall in the short rainy season, a departure from what has been happening historically. This has led farmers in some parts of Trans Nzoia County to start planting maize twice a year. Due to the changing weather patterns, farmers in Trans Nzoia have started cultivating crops that were hitherto not grown, such as sorghum. Farmers have also reported very low temperatures in areas such as Cherang'anyi or high temperatures near Kiminini.

3.3 Climate Vulnerabilities across Agricultural Value Chain Commodities

3.3.1 Maize

Moisture stress and uncertainty about the start and end of the growing season were identified as the two most important hazards for the maize value chain. Uncertainty about the timing of the growing season affects decision making, the availability of funds, and the acquisition of inputs, since most farmers are small-scale and have meagre resources. Some farmers end up not applying inputs needed for optimal production, which reduces their productivity. The impact of this hazard is major at the input acquisition stage since delays in obtaining inputs or the inability to use them can result in lower yields. Uncertainty about the start and end of the growing season also leads to increased production and land preparation costs. Maize germination rates decline because of repeated land preparation or input buying to replant. The late onset of rains might interfere with the harvesting calendar, leading to post-harvest losses due to rotting. These challenges have a major or even a severe impact on the value chain. The quality of the harvested produce is compromised by the buildup of high aflatoxin levels caused by excess moisture. Decay reduces the amount of grain available for processing and sale. These impacts on the value chain are moderate to severe. Uncertainty during the production season adversely affects output markets. The disruption of the supply chain causes scarcity as the supply of grains fails to meet demand, distorting or increasing market prices, which has a major impact on the value chain.

Because it affects decision making, moisture stress reduces access to the inputs required for optimizing production. Farmers cannot access credit facilities to acquire inputs since they are considered high-risk by lending or credit institutions. These difficulties have a major or severe impact on the value chain. The costs of on-farm activities rise due to difficulties in land preparation caused by panning and due to reduced maize seed germination rates that depress yields. The impact of these challenges to on-farm activities ranges from minor to severe. On the other hand, moisture stress has major positive impacts on post-harvest activities. It enables easier shelling and drying. Transport infrastructure is not affected, and thus market access is easy. In output markets, however, low grain volumes can drive up prices, with a major impact on the maize value chain.

Farmers enhance their resilience by adopting some coping strategies (Figure 11). The county governments have offered them subsidies for inputs such as seeds and fertilizers to cushion them against climatic risks. Some farmers have resorted to using recycled or their own seeds instead of improved varieties, avoiding the costs incurred from buying seed. Farmers practice early land preparation and dry or early planting in order not to be caught off-guard by the vagaries of the weather. If the means are available, others opt to use mechanized land preparation and planting where the land has developed hard pans. To address poor germination rates, farmers might increase seed rates and replant. Farmers have shifted from planting maize cultivars that take 6 months to ripen, to earlier-maturing varieties that take an average of 3 months. In some areas of Trans Nzoia County, they have begun planting maize for two seasons as opposed to one, which had been the norm. Farmers are now using driers to dry their maize as opposed to sun drying, which ensures the right moisture content for the maize to reduce rotting and aflatoxin levels. In terms of storage, the use of hermetically sealable bags has gained currency to reduce post-harvest losses. The bags store the grains for longer as farmers wait for better prices. Some farmers sell green maize rather than the dry grains to reduce post-harvest losses.

3.3.2 Beans

Uncertainty about the start and end of the growing season and excess rainfall were identified as the most important climate hazards for the beans value chain.

Uncertainty about the timing of the growing season affects decision making in bean production, since farmers are caught off-guard by the unexpected onset of rains or by delays in acquiring crucial inputs, with moderate impacts on the value chain. This hazard also affects on-farm production activities such as land preparation, planting, and harvesting, and interferes with the harvesting calendar. Prolonged rains can heighten post-harvest losses. Diminished yields, meanwhile, shrink economies of scale and lessen farmers' bargaining power, elevating post-harvest processing costs per unit; these problems are often accompanied by quality reductions. Lower production and lower quality results in farmers losing income. Apart from farmers, businesses and traders involved in the beans value chain are adversely affected due to decreased volumes of inputs sold and produce traded as a result of uncertainty. The severity of these impacts ranges from moderate to major.

Excess rainfall, on the other hand, results in the destruction of road infrastructure, which in turn reduces or precludes accessibility. This hazard affects the acquisition of inputs due to delays in reaching markets. It also causes input shortages, which trigger price increases and raise production costs. Farmers are forced either not to use the recommended inputs at all, or to utilize quantities lower than are requisite for optimum production. On-farm production is affected by difficulties in land preparation, planting, and harvesting. Additional impacts might include a surge in pests and diseases, exacerbated soil erosion, the leaching of nutrients, and in extreme circumstances, total crop loss. At the post-harvest stage, costs rise for labor and transport, and rotting can occur. In output markets, the effects are twofold. Firstly, the prices for farmers are depressed due to the poor quality of the produce. Secondly, the supply chain is disrupted; low volumes of produce reach the market, causing high prices for consumers. The severity of these impacts ranges from moderate to major.

Farmers have implemented a raft of adaptive measures to cope with these variabilities and changes in the climate. They may use their own or recycled seed, organic manure, and locally improvised pesticides (concoctions made from herbs). To circumvent climate variability, farmers also engage in dry planting and sustainable land management practices such as the construction of terraces and drainage. At the post-harvest stage, farmers hire additional laborers to harvest and process their crops, and they use draught power as means of transport to reach market centers. Information sharing through phones and social media platforms enables farmers to access market information.

3.3.3 Dairy Cow

Moisture stress and excess rainfall resulting in flooding are the two main hazards affecting the Dairy cow value chain. Moisture stress increases the cost of production through high feed prices caused by scarcity. It also drives up breeding costs as result of high extension services costs and the use of multiple or repeat artificial insemination (AI) services. The impacts of these consequences are moderate. During incidences of moisture stress, feed shortages occur due to low fodder growth rates, negatively impacting the amount of milk produced. It becomes more difficult to control diseases such as foot and mouth since farmers allow their animals to roam for new grazing, resulting in disease outbreaks. These problems have a major impact on the value chain. Moisture stress leads to reduced volumes of milk for bulking, transportation, and processing. In output markets, farmers are unable to meet the demand for milk, triggering price increases for farmers and consumers.

Excess rainfall results in increased risks of flooding and infrastructure destruction, thus disrupting the provision of services such as AI, extension, and the acquisition of feeds. The impact on input supply ranges from minor to major. During excess rainfall events, fodder growth rates are reduced due to too much moisture, creating shortages. Outbreaks of diseases such as rift valley fever occur. The effects of this hazard include lower production of milk, and the impacts are major. Roads rendered impassible by excess rains cause delays in milk collection and deliveries, heighten transport costs, and exacerbate milk spoilage. Processors have less milk to process, increasing unit costs. These impacts range in severity from moderate to major. Excess rainfall delinks farmers from output markets, resulting in milk spoilage and income loss. Adverse effects on the milk supply chain are moderate.

Farmers have embraced intensive dairy cattle management systems such as zero grazing to counter the adverse effects of these climatic hazards. These systems restrict the movements of the animals, thus prevent disease outbreaks. Mass vaccinations are routinely undertaken by the County veterinary department to forestall disease outbreaks during adverse climate events. Feed conservation measures such as making silage and hay from drought-tolerant fodder like Brachiaria grass have been adopted by some farmers to address shortages. Farmers are also increasingly using crop residues such as maize stover to supplement green fodder. In addition to the above measures, farmers are improving the genetic makeup of their dairy cattle to increase resilience and production capabilities. They are implementing sustainable land-use management practices such as constructing terraces to mitigate flood risk. Farmers have embraced group formation to benefit from economies of scale in terms of milk collection, aggregation, and transportation. They have formed and joined cooperatives, which offer various benefits such extension services, input acquisition, and milk marketing. They rely on motorcycles for easy access and to carry milk, using the recommended aluminium churns to reduce spoilage.

It is important to note that in Trans Nzoia County, a majority of the population is affected by climate change. Women bear the brunt of the impacts, since they are most heavily involved in on-farm production. This stage is where the bulk of the heavy workload falls. Women and children are affected most acutely when crop failures occur, since this has a direct impact on food security and the nutritional status of their households. Women rarely have alternative sources of income as compared to men.

3.3.4 Indigenous Chickens

Uncertainty about the start and end of the growing season and moisture stress are the two major climatic hazards that affect indigenous chickens in Trans Nzoia County. Uncertainty about the timing of the growing season drives up production costs because delays in rainfall can cause feed scarcity, which in turn elevates prices. Inadequate and poor-quality feeds can cause nutritional deficiencies, which may result in a heightened incidence of disease and hence, may cause farmers to spend more resources on treating birds. Input supplies are moderately affected. Egg production may be jeopardized by feed scarcity and diseases. On-farm production faces minor-to-major impacts. Fewer birds are taken to market as a result of diseases. Reduced body weights caused by scarce and expensive feeds result in less feed being given to the birds. Farmers cannot afford the necessary feed stocks. Uncertainty about the timing of the growing season has moderate-to-severe impacts on the post-harvest stage. Consequently, in output markets, the birds fetch lower prices, so farmers lose income. Output markets also experience reduced volumes of birds. These impacts on output markets are moderate to severe.

Moisture stress increases production costs due to a variety of factors: low egg hatch rates, expensive feeds, and ineffective vaccination regimes caused by low vaccine availability. Regular chick-rearing supplies are adversely affected. The impact on input supply is major. On-farm production is moderately affected by low feed supplies and increased disease incidences. Egg production is also adversely affected; low volumes of eggs hatch. Breakage and spoilage of the eggs occur during transportation due to moisture stress. These impacts are moderate. Farmers additionally incur losses due to depressed egg numbers delivered to output markets with moderate-to-major impacts on the value chain.

Indigenous chicken farmers have employed several adaptive measures to cope with climatic variability. They use improved incubators such as solar incubators to boost hatchability rates. During chicken feed shortages, farmers allow their birds to scavenge through free-range management systems. Farmers use local herbal concoctions to protect their birds against diseases when the efficacy of vaccines is compromised. They have bought coolers to transport vaccines and carry out vaccinations themselves. To minimize bird deaths and egg breakages during transport, they have also embraced the use of improved cages and crates. Farmers have learned how to formulate their own feeds to lower the costs of commercial feeds. In addition, they have formed and joined producer organizations to help them with services such as input acquisition, the bulking of birds, information, transportation, and marketing their birds and products. Collective action through producer organizations has helped farmers navigate climatic hazards.

4. Adaptation to Climate Change and Variability

4.1 Factors Determining Future Variability and the Impacts of Climate Change

Farmers in Trans Nzoia County are prone to experience the impacts of climate variability due to various economic, infrastructural, institutional, and policy-related factors. The elevated poverty rates in Trans Nzoia County coupled with the high costs of climate change mitigation technologies make farmers more vulnerable. Poor infrastructure also heightens their vulnerability by negatively affecting access to inputs and markets for their products, especially when the county is affected by excess rainfall. Biophysical factors such as location, altitude, and terrain may also worsen the vulnerability of farmers by affecting the amount of rainfall received, erosion rates, flooding. For instance, Trans Nzoia County contains areas such as the Cherang'any Hills that are prone to soil erosion due to heavy rainfall and steep terrain. Flooding is experienced along the River Sabwani. Suboptimal institutional capacity has led to poor access to information and low uptake of technologies by farmers. Meanwhile, a lack of policies has negatively affected farmers' efforts to acquire inputs and market produce. Culturally and socially, women are more vulnerable to climate impacts because of low access to production resources.

4.2. Climate Change Adaptation Options

4.2.1 Ongoing Adaptation Practices

Farmers in Trans Nzoia have enhanced their resilience by employing numerous on-farm and off-farm measures to ameliorate the effects of climatic variability (Figures 11). They have been using knowledge about the behavior patterns of certain insects and pests to predict when the rains will fall. These efforts complement the weather advisories from the meteorological department. Farmers also use their own or recycled seed when faced by climatic hazards if their meagre resources do not allow them to purchase seed. Early-maturing maize varieties such as HARAKA, Sungura, and 5 series (524,516) have been adopted by farmers as a way to help address uncertainties around

the onset and end of the planting season. These varieties take an average of 90 days to mature – far less than the 5-6 months required by the conventional 6-series varieties farmers in Trans Nzoia County had been planting.

To reduce labor costs associated with addressing climate hazards, farmers are increasingly implementing on-farm measures such as mechanization for land preparation and planting. The promotion of sustainable land-use management practices is enabling farmers to build their resilience. These practices include the construction of terraces and cut-off drains to mitigate the effects of flash floods caused by excess rainfall. Farmers in Trans Nzoia County also practice conservation agriculture, such as minimum tillage, mulching, and using cover crops. For horticultural crops such as tomatoes, farmers have embraced use of greenhouse technologies, while others practice drip-irrigation along riverbanks and near other water sources. Water harvesting through roof catchment and drilling underground boreholes enables farmers to improve their access to water for home and agricultural use. Farm agroforestry is being encouraged by organizations such as Kenya Forest Service (KFS). Projects like NARIGP encourage agroforestry so that farmers plant trees like grevillea, avocados, and mangoes. These trees are also planted along contours to act as soil stabilizers and wind breaks.

Dairy farmers are transitioning from extensive to intensive management systems wherein zero grazing is gaining traction. Cattle keepers are increasingly using AI to improve their breeds. The county government is supporting regular mass-targeted vaccination to prevent disease outbreaks. In terms of on-farm practices, farmers plant drought-tolerant fodder species such as *Brachiaria* grass, which has high protein content and can withstand harsh weather conditions. In addition, this fodder is used in hay making. Dairy farmers conserve forage through silage and hay making to ensure a steady supply of feeds and address any shortfalls occasioned by climatic hazards. Poultry farmers, meanwhile, give preference to indigenous chickens as opposed to broilers and layers. Indigenous chickens are hardier and can withstand climatic variability better than broilers and layers.

Diversification of agricultural and livestock enterprises is a popular farmer adaptation strategy. Diversification enables farmers to spread their risk across enterprises that might be more resilient to weather vagaries. Trans Nzoia County has seen a shift from traditional crops like maize and beans to other crops like bananas, avocados, tomatoes, coffee, and potatoes. These latter crops help farmers hedge against climate risks, which affect different crops differently.

Despite striving to undertake adaptive measures to mitigate the effects of climate change and variability, farmers face several hurdles. Some adaptation interventions are expensive, so resource-poor farmers are financially constrained. In addition, farmers lack information about interventions and the technical knowledge to implement them. Farmers have inadequate access to extension services that might ameliorate this situation due to insufficient human capacity in relevant government departments. Implementers of adaptation interventions also face logistical challenges which adversely affect their service delivery.

4.2.2 Potential Adaptation Practices

Farmers in Trans Nzoia County have undertaken various adaptation practices to mitigate their climate-related vulnerabilities, yet more could be done to ensure that they are cushioned against the negative impacts of climate change (Figures 11). Conservation agriculture could be scaled up. Continuous research on new varieties that can withstand climate variability would support the use of improved seed varieties. Encouraging Integrated Pest Management could help tackle the emergence of pests and diseases associated with climate variability. Continuing construction of water conservation structures and sustainable land management practices can improve drainage and water retention. Contract farming between farmers and produce buyers can hedge the farmers against losses. New policies might guard farmers against exploitation by input suppliers and produce buyers.

Extension services and building farmers' capacity for modern and efficient agricultural technologies could also be upscaled. These technologies include farming methods, feed formulation, suitable breeds, feed preservation and conservation, the use of hydroponics in feed production, the drying of cereals, winnowing technologies, storage, and value addition. Upscaling timely and appropriate weather advisories to farmers would empower farmers make informed choices. Crop and livestock insurance could be promoted through awareness creation and information about available insurance products.

Producer organizations could be strengthened to leverage farmers' collective action. Such organizations can have many benefits: enabling individuals to acquire services and inputs including seed, fertilizers, feeds, and AI; providing extension services; marketing farmers' commodities; and value addition. Some producer organizations have check-off systems in place that allow farmers to access services on credit. Producer organizations can also improve the bargaining power of farmers when selling their produce.

Adaptation strategies used in selected value chains in Trans Nzoia County

Beans

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Excess Rainfall Consequences	Affects site-selection decision making; high feed & transports costs due to impassable roads; high pesticide costs due to high demand	Causes soil compaction and erosion leading to high land-preparation costs (i.e. increase in labor during planting and machinery costs); high pest and disease incidence (high labor and pesticide -application costs); low yields, and poor produce quality	High transport and labor costs; poor road accessibility from farm; threshing difficulties due to high moisture content; reduction in produce quality; high labor costs; extended drying periods; high losses due to rotting/spoilage	Reduced sales prices due to poor quality, and reduced market volumes leading to consumer price increases; reduced market access with weather roads; increased transport costs; reduced sales due to excess rainfall, interference with market centers' activities
Magnitude of Impact	Moderate-Major	Major	Moderate-Severe	Moderate-Major
Farmers' Current Coping Strategies	Acquiring land in higher altitudes; using seeds with high tolerance to excessive rainfall; using organic/ indigenous pesticides (pepper, wood ash)	Ploughing along contours, and only during dry season to reduce surface run off; practice dry planting; hiring more labor and spreading tarpaulin during harvesting	Using animal draft power; constructing drainage channels; spreading in grain store to reduce moisture content; grading grains; storing using hermetically sealable bags until weather improves; hiring more labor for drying, sorting and grading	Increasing sorting and grading labor in to command good prices; in cases of low prices farmers recycle seeds from previous harvest; farmers selling to other farmers or middlemen to reduce transport costs; selling at farm gate; traders using modern market stalls
Potential Adaptation Options	On-farm water pan construction to harvest excess rainfall; scale up seed supplies for varieties tolerant to excess rainfall; upscaling organic pesticides use	Terrace construction; adapting to weather advisories from weather forecasters	Government should construct all-weather roads with good drainage systems to facilitate transportation even during excess rainfall; adopt current technology for threshing and winnowing beans e.g. threshing machines; using seed driers equipment and modern grain/cereal storage facilities to increase seed shelf-life	Diversifying bean varieties to take to market; adopting digital marketing and cooperatives' platforms to link with consumers; conducting pre-market consumer needs surveys to inform production plans
Underlying Factors	Economic factors: the poor affected as they lack resources to acquire inputs and are vulnerable to high input prices; bio physical factors: areas with low lying clay soils affected	Economic factors: inadequate resources for women and youth; institutional factors: lack of policies for creating awareness governing bean value chain; culture: some communities believe labor is provided by women and youth	Infrastructure: poor road networks, lack of/inadequate drying facilities; social/cultural - most communities believe that winnowing and threshing is done by women and youth; economic: lack of resources for youth and women to venture into new technology	Institutional: inadequate information on current market trends for women; economic factors- inadequate resources to venture into large-scale enterprises to bulk up the produce; infrastructure - impassable roads during excess rain to link farmers
Uncertainty in the Onset of Rains and Growing season Consequences	Affects decision making whether to acquire land due to unpredictable rainfall patterns; reduced sales for agro-dealers and farmers	Uncertainty regarding best time for land preparation hence delays and poorly prepared land; in case of early rainfall onset, farmers ill-prepared for planting; planting plans becomes difficult; prolonged dry spell leads to seed germination delays ; interference with harvesting calendar and prolonged rainy season leads to beans rotting and reduced yields	Change post-harvest calendar; interfere with transport planning; interference with plant operation for threshing and winnowing; storage facilities may not be in place- prolonged wet season affects drying and storage	Unpredictable market trends; loss of contracts especially if supplying to institutions; inability to honor the buyers' contracts; reduced sales leading to reduced profits which affects livelihoods
Magnitude of Impact	Moderate-Major	Moderate-Major	Moderate	Moderate-Severe
Farmers' Current Coping Strategies	Diversification into other crop enterprises; farmers using recycled seeds; using indigenous technical knowledge (ITK) e.g. using ash, pepper	Waiting until the rainy season starts, dry planting; using organic manure; planting in two seasons; hiring more labor during harvesting; spreading grains in storage structures and covering with tarpaulins	Using draft power for farming, using manual labor to transport from farm; using tarpaulins during threshing and winnowing; using spacious storage structure for threshing; hire more labor; using sun drying for drying beans; increase labor for drying	Pricing information sharing between farmer to farmer, through social media and market places; information sharing between farmers; sourcing beans from other markets; planting beans in two seasons to get more for selling
Potential Adaptation Options	Adopt using weather advisory from meteorological department; Adopting weather information sharing platforms and technologies e.g. Yara weather mobile app, met platform; get accurate regular weather updates	Liaise with weather/extension service providers on appropriate time for land preparation; Encourage planting on second season, mono-cropping for beans, planting short season's bean varieties; using extension advisory for timely farm operations	Liaising with weather advisories service providers in post-harvesting activities planning; Using modern technology for threshing and winnowing, and drying and storage e.g solar driers, grain storage stores	Beans pricing should be included in county policies; Using digital platforms in quoting prices of bean produce; formulation of cooperatives to help set prices and link buyers to farmers, enhanced extension services; increase acreage in planting season and bean varieties; capacity building to farmers/traders on varieties of beans which can cope with uncertainties
Underlying Factors	Economic: losses incurred to acquire land process in case of late onset of growing season; institutional-agro-dealers and farmers have inadequate information on varying onset of growing season	Infrastructure: majority of farmers during rains require machinery which is not readily available; economic factors- high operating costs	Economic: inadequate resources to procure transport production equipment/machinery; culture: most community members believe threshing done by men and winnowing is done by women; inadequate modern storage facilities; low farmers' capacity building on best/appropriate post-harvest solutions	Economic factors: leads to unpredictable price fluctuations due to unpredictable produce volumes which affects profitability; social factors: loss of trust in supply contracts; infrastructure: poor road networks which hinder market accessibility during rains even when crops are ready

Maize

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Moisture Stress Consequences	Lender withholds release of funds; economic loss due to reduced leasing; reduced rental costs; input prices especially fertilizers reduce (positive for farmers); changes in seed variety usage thus affecting output; low demand for maize inputs	Ploughing land becomes difficult due to hard pans; poor seed germination, wilting seedlings and staggered growth or crop failure; assists in drying maize and increases farm accessibility (positive for farmers); little or no maize to harvest	Enhances on-farm crop drying which is a positive consequence for farms; less produce for shelling; drying process easier; may cause on-farm fire outbreaks; less produce for storage and processing	Increased produce prices due to reduced yields; positive impact due to passable rural roads; leads to reduced output sales at higher prices; ready market
Magnitude of Impact	Moderate-Severe	Minor-Severe	Minor-Major	Major
Farmers' Current Coping Strategies	Using last season's produce as capital and leasing part of own land to generate capital; advancing land leasing by farmers; price reduction by agro-dealers; agro-dealers providing extension services as after sale services; adopting drought-tolerant and early-maturing varieties; receiving government subsidies	Applying herbicides to reduce livestock grazing which causes hardpans; harrowing farms; implementing conservation agriculture i.e. minimum tillage; replanting, gapping and converting failed crop to silage; using herbicides, weeding manually and integrated pest control	Influx of imported maize; planting maize for two seasons instead of one	Reduced consumption of maize produce; introducing pricing and movement policy concerning produce
Potential Adaptation Options	Advancement of low interest loans to farmers; crop insurance; promote using climate smart agricultural practices; adoption of conservation agriculture; enhance research on suitable seed varieties e.g. GMO; enhance homemade manure preparation and application; using slow release fertilizers	Using farm machinery to break hard pan; using cover crop to conserve moisture; using planters; adoption of climate smart agriculture; avoid planting with manure and time application on the rainfall onset; promote biological weed control methods; research on weed tolerant varieties, and integrated pest management	Adopt seeds that can be grown for two seasons and improve on the strategic food reserves	Investment in food reserve mechanisms and development of sustainable government policies on maize produce
Underlying Factors	Economic factors: small-scale farmers may divert resources to immediate needs when onset delayed; stockists remain with dead stock for long periods since buyers are hesitant; potential leasers abandon farms due to onset uncertainties	Economic: farmers affected most by repeating land preparation and planting while stockists will benefit; lack of resources to buy extra inputs	Economic factors: laborers/casual workers most affected since drying process is easier (they may not be needed on-farm for drying purposes)	Economic factors: prices increases with moisture stress thus consumer is affected most; policy factors: cross-border free trade affects farmers most as cheap imports are freely allowed
Uncertainty in the Onset of Rains and Growing season Consequences	Lenders withhold funds; farmers redirect funds to other uses; economic loss due to leasing/ re-leasing due to uncertainties; excess leasing by landowners leaving them with no land for farming; input price fluctuations during uncertainties	Repeating land preparation which increases production costs; poor germination resulting in replanting (where possible); yield loss due to planting after rains' onset; decay of maize in farm, difficulty in accessing farm during harvest due to muddy conditions and poor harvest if rainfall cessation comes early	Crop decays when rainfall cessation delayed; aflatoxin build-up on maize produce; prolonged season damages stored product through decay; early cessation positively impacts crop drying process; uncertainty impact s produce availability for millers/processors	Delayed rainfall onset will increase prices while early rainfall onset will reduce prices; grading easier with early rainfall cessation but difficult with late rainfall cessation; early onset, late onset, and late cessation of rainfall will affect transportation negatively due poor roads or state of harvested produce; early rainfall onset increases sales, late onset reduces sales, early cessation increases sales with lower prices, while late rainfall cessation reduces sales due to poor quality harvest
Magnitude of Impact	Moderate-Major	Major-Severe	Moderate-Severe	Major-Severe
Farmers' Current Coping Strategies	Seeking alternative capital sources; leasing land; joining farmers' processing/ producer groups and production of on-farm manure, and reducing inorganic fertilizer application rates	Timely dissemination of information on rainfall onset and cessation; mechanized planting, dry planting, irrigation if land is near water source, and relying on weather forecast	Market timing to sell at good prices (storage to time market), selling of green maize; bulking maize by small-scale farmers for better bargaining power; farmers prefer selling at farm gate; hiring appropriate transportation through pooling, and temporary grading of roads; selling to brokers, changing use of produce e.g. use as animal feeds, sale to millers where there is scarcity	Using dryers and shellers, and sorting cobs; using hermetically-sealable bags, insecticides, fumigation and warehouses; proliferation of small-scale millers
Potential Adaptation Options	Warehouse receipt system; subsidies by government agencies, forming producer organizations for maize value chain; maintaining conservation grade soil structure, preparing own farm manure, farmers savings-embracing saving culture for farming inputs; using slow-release fertilizer	Applying conservation agriculture adopting manual planters for small-scale farmers	Increasing millers for value addition, and managing price fluctuations and by-products; county government goodwill to promote major millers in county Increasing number of millers and warehouses	Adopt maize varieties that are not susceptible to lodging, disseminate dryer services to all farmers, and producer organizations should assist farmers in acquiring dryers; adopt warehouse receipt system and promote portable silo usage
Underlying Factors	Economic status: small-scale farmers may not have resources to replant when onset is uncertain; infrastructure: input supplies disrupted if onset is earlier than expected due to poor road conditions; institutional: poor uptake of climate information from relevant institutions especially for illiterate farmers	Economic factors: small-scale farmers affected most due to poor germination and they are not able to replant due to cost implications; millers and small-scale farmers affected most when rainfall cessation delays thus decaying crops on-farm; institutional factors: planting times affected especially for farmers with no access to weather forecasts	Late cessation affects small-scale farmers more as crop may not dry adequately; late onset affects farmers, millers etc. due to poor crop quality and quantity; economic factors: poor harvest and reduction of income	Farmers suffer most with late rainfall cessation as crop quality and quantity reduced; infrastructure: late cessation makes roads impassable thus affecting transporters and farmers; social cultural factors: crop revenues normally controlled by men, disadvantaging women and youth; bio-physical factors: nature of terrain affects transportation

Chicken (Local)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Moisture stress Consequences	Poor hatchability affects day-old chicks' supply; high feed formulation material costs; ineffective vaccines resulting from transporting and poor handling leading vaccine viability loss ; flock losses due to disease outbreak	Readily available on-farm and durable chicken housing material; controlling extreme temperatures are labor intensive; lower feed intake affects growth rate and reduces egg production; pest and disease increases (e.g. coccidiosis, fowl pox, and infectious coryza)	Decreased egg production due to stress; spoilage at egg bulking due to high temperatures; losses during transportation; increased preservation and transport costs	Loss during transportation, low chicken demand and low sales; increased advertising and promotion costs, low farmers' bargaining power, less profit realized; low prices; less opportunities due to poor product performance
Magnitude of Impact	Moderate-Major	Minor-Moderate	Moderate	Minor-Major
Farmers' Current Coping Strategies	Improving self-hatch by manually providing moisture; farmers resort to buying chicks at older stages than one-day chicks and increase number of hatcheries; incubators donated to farmer groups and individual farmers; sourcing cheaper raw materials from Uganda, using type cereals "Mwoze maize"; free-range rearing, grow own crops to do own fed formulation using farm byproducts; resorted to traditional methods using herbs; ice packs for farmers doing self-vaccination	Using adjustable canvas curtains on airspaces to moderate temperatures; increasing number of drinking containers available for chicks to ensure hydration; using semi-intensive methods like a protected run (where chicks come in and out); free range; supplementing from kitchen waste; using whole grains; traditional practices/ ITK , limit visitors to chicken houses or using foot baths; using information technology(IT) to obtain information and technical advice from experts; capacity building by the ministry and other organizations	Using amino acids and vitamins; using egg boosting supplements in feed and drinking water; capacity building on egg collection and storage; keeping produce in cooler places in the home and improving ventilation; using cages and crates during transport	Forming farmer groups to improve market access; joining social media platforms like M-shamba; poultry farmers WhatsApp groups; farming of common interest groups; joining producer organizations; improved fast-maturing breeds; improved feeding options,and group marketing
Potential Adaptation Options	Capacity building for farmers at different input levels e.g. egg picking and handling; using incubators and hatcheries; providing solar powered incubators to reduce electricity and fuel costs (even large-scale); opportunity for serial bulking to be used during dry season; policies formulation that favors farmers; strengthen the cold chain and farmers' capacity building	Technology for using solar powered fans and capacity building for production; on-farm feed formulation; promoting proper feed mills and mixers; capacity building; vaccination program development and implementation	Facilitating the producer organizations with coolers and appropriate bulking space for eggs, live chicken or processed meat	Capacity building on sustainable production by staggering ages of growth to have chicken throughout the year; strengthen capacity of POs to meet farmers' needs; embrace new ways of marketing platforms e.g. WhatsApp business, Facebook, and market groups; support and fund farmers' benchmarking for motivation and eye-opening opportunities to produce poultry for business
Underlying Factors	Men, women and youth are affected by policy factors- lack of subsidies at county and national levels; cultural factors: women carry burden of work but don't control income; economic factors: low incomes and no alternative income-generating activities; high production costs-e.g. electricity bills; social factors: vulnerable and marginalized unable to handle day-old chicks and hence buy at one month	This industry is driven mostly by youth and women; the value placed on poultry for use at ceremonies and festivals, or even as a source of income in times of need, is a socio-cultural constraint to poultry development.	Institutional factors: lack of value additions know how; infrastructure status: lack of innovative technology or equipment for value addition	Women, vulnerable and marginalized farmers are more affected; institutional factors: farmers have not learnt to embrace alternative ways of marketing e.g. social media; biophysical factors; poor terrain makes markets inaccessible; policy factors: lack of proper marketing policies makes farmers more vulnerable to exploitation
Uncertainty in the Onset of Rains and Growing season Consequences	Increased feed prices due to low supply of raw materials; low egg supply due to poor feeding; high egg costs leading to high chick costs; expensive feeds, high production costs; reduced productivity, mortality risks, nutritional deficiencies	Missed opportunity for constructing and improving housing structures; high production costs with increased feed prices; cannibalism due to insufficient feeds; missed opportunity due to fear of investment risks	Reduce egg production and reduced profits; low volumes makes transportation expensive; poor slaughter weight and low prices	Affects bargaining power due to poor slaughter weight; products not competitive; fetching low prices thus low profits and income for farmers; loss of market
Magnitude of Impact	Moderate	Minor-Major	Moderate-Severe	Moderate-Severe
Farmers' Current Coping Strategies	Growing of crops for own raw materials; sourcing cheaper options e.g. Uganda market; using solar powered incubators on small scale; ITK (self-hatch practices) e.g. using local breed- synchronization hatching; selection of good breeding flock avoids in-breeding; using a vaccination schedule	Being in touch with on-farm information-givers; using weather advisories to make decisions; using homemade feed variations and cheaper, readily available feeds and raw materials; diversification to other business	Learn other feeding methods, joining Common Interest Groups (CIGs); resort to wholesale average prices on a flock	Group marketing; wholesale pricing averages for entire flock; alternative sources of income, and improved breeds
Potential Adaptation Options	Capacity bulking on staggered hatching; providing technical and economic business support; using early-maturing varieties on contract farming and stock for future use; enforcing quality policy making and use to protect farmers from exploitation; using cooler and cold chain at producer levels; providing employment opportunities for youth and women to technically support farmers	Introducing solar-powered fans and capacity building on housing and production; embracing technology for alternative feeds like hydroponics and capacity building; observing biosecurity measures	Using hydroponics and vermiculture technologies; capacity building or proper feeding and nutrition programs; identifying breeds for business e.g. sasso and kuroiler	Strengthening Pos' capacity ; establishing poultry hubs to cater for whole value chain; capacity building on financial literacy and contract farming for poultry farmers; supporting improved breeds, offering poultry insurances
Underlying Factors	Social/cultural: they don't own property /land; institutional: low capacity to mitigate; economic status: no buffering alternative income sources; infrastructure: no alternative technology and know-how e.g. for hydroponics to supplement feeds or implementing self-hatch systems	Economic factors: low income, high production costs; institutional factors- low capacity, cultural factors: don't own the land to build poultry housing structures; infrastructure: lack of feed formulation equipment, lack technical capacity for disease control; policy factors- high tax, feeds, electricity, transport and equipment	Institutional factors: capacity for value addition technology is low; economic factors: low income forces reliance on hired transport; infrastructure factors: aggregation centers not yet fully functional; biophysical factors: poor terrain affects how goods reach markets e.g. Saboti- Kitwamba, and Kinyoro wards - the whole subcounty has poor road networks; endeless mutumbai, chepchina; Kwanza- Kupumboi soi mining	Economic factors: lack of funds to reach the right target market and volumes; social factors: they have no bargaining power as they have not joined existing marketing cooperatives; institutional factors: lack of sustainability in supply due to weak institutional structures e.g. for contract farming where farmers stagger produce supplies to be available all year round affecting quality and volumes

Dairy (Cow)

	Provision of Inputs	On-Farm Production	Harvesting Storage and Processing	Product Marketing
Moisture Stress Consequences	Heat stress limits animal exhibitions of oestrus signs making farmers miss that cycle and creates need for more repeat breeding; limited feeds to maintain the body physiological hemostasis and functionality; moisture stress leads to inadequacy or limited access to raw materials leading to high feed costs and feed scarcity; moisture stress leads to inefficiency in cattle productivity which in turn increases demand for veterinary and extension services leading to high production costs	During prolonged drought, there will be inadequate cattle feedstocks and increased feed prices; decreases in pasture quality due to moisture stress; moisture stress makes disease control difficult due to illegal movement of animals from various places in search of food; reduced volumes to be milked, reduced workload for farm laborers	Moisture stress reduces milk production, therefore, less volume available during bulking and storage thus increasing unit production costs; reduced milk volumes available for transportation increase transport costs; moisture stress leads to scarcity and inadequacy of raw materials for processing, leading to high processing costs	Inadequate products to be promoted; inability to meet market demand for the product due to shortages during moisture stress; higher prices for the scarce commodity; reduced farmers' ability to meet milk and milk product demands
Magnitude of Impact	Moderate	Moderate-Major	Minor-Major	Moderate-Major
Farmers' Current Coping Strategies	Housing the animals to mitigate heat stress effects; planting suitable varieties for silage making (Rhode grass), silage and hay making, and stocking in anticipation of drought; extension is demand- driven due to lean staff, field days deliver the extension services closer to farmers	Using locally available residues e.g. maize stovers during dry season; conserving feeds through silage and hay making, and stocking; disease prevention and control strategies in place e.g. livestock vaccination; downsizing farm labor during moisture stress and uptake of farm mechanization to reduce labor costs	Improving livestock genetics to ensure enough milk to be bulked; make use of dry feeding to maintain or have constant production for bulking; bulking and transporting as group/cooperatives to utilize economies of scale; using cost-effective means of transport during scarcity e.g. motorcycles; mobilize and contract more farmers to ensure enough quantities for processing; making powdered milk for use during shortage	Preservation of milk during peak periods to sell during scarcity; link with other producers to meet demand; purchasing milk from other areas during shortage to meet market demand and maintain customers
Potential Adaptation Options	Research on suitable heat-tolerant breeds and breeding programs; research on suitable nutritious feeds that can go all seasons e.g. Bracharia spp. for fodder; capacity building for farmers to encourage adoption of technologies for on-farm feed formulation and preservation; link farmers to existing online extension platforms or create more where lacking; have more media extension services through radio, TV, and other channels	Upscaling on farm feeding formulation, preservation/conservation technologies; planting drought resistant fodder crops such as sorghum for feeding during moisture stress periods; design new policies & regulations to regulate livestock movement, and create or upscale awareness on livestock vaccination; small scale farmers should invest in farm mechanization while large scale farmers should upscale to using milling machines	Upscaling technologies to improve/ ensure constant production across the season; using cost-effective energy sources e.g. solar for cooling; upscaling cost-effective means of transport; upscaling farmer recruitment to ensure quantities for processing; investing more in preservation equipment for excess milk during peak season	Invest more in milk preservation to have products for promotion in the future or during scarcity; expand capacity on value addition to prolong milk shelf-life for sale during shortage; re-negotiating contracts to avoid penalties during shortages
Underlying Factors	Biophysical factors: some areas are more drought prone due to geographical location e.g. Keiyo ward, chepchoina; economic factors: cannot buy feeds/have low purchasing power; institutional factors: lack of technical knowledge on feed preservation and using locally available farm produce	Biophysical: uneven distribution of rains; institutional factors: lack of information or know-how to mitigate moisture stress; policy factors- illegal cross-border movement of animals and poor enforcement of regulations	Economic factors: high operating costs of processing plants when produced volumes are low; institutional factors: less milk due to lack of knowledge of how to maintain production quantities through the year; infrastructure: poor or impassable seasonal roads	Institutional factors: less knowledge on how to produce adequate milk throughout the year in all seasons; infrastructure: lack of equipment that would assist in preserving excess milk produced during productive seasons for use or sales during seasons with less production or shortages
Excess Rainfall Consequences	Seasonal roads become impassable leading to difficulty in accessing farms thus causing delay in service delivery; cycle loss and waste of production calendar for dairy farmer and high production costs due to repeat breeding and longer breeding calendar; inadequate feeds due to forage and pasture destruction by floods leading to raw materials scarcity; during floods, there are unfavorable weather conditions for feed preservation; leads to production loss due to poor animal health	Leads to livestock feeds scarcity due to pasture and fodder crops destruction ; leads to increase of biting flies that are diseases vectors; likelihood of disease outbreaks increases such as rift valley fever; floods may lead to displacement of both farmer and livestock due to destruction of farm structures	Impassable roads constrain access to bulking sites leading to milk spoilage, produce loss, and milk delivery delays to end users; manpower loss due to accidents, wear and tear thus increasing transport costs; raw materials don't reach processing plant in time	Physical movement for milk and milk products promotion is hampered during flooding; gatherings during flooding create room for promoting dairy products; floods cut off products from markets, losses due to high perishability of milk; increased cost when linking farmers to buyers or processors; fewer buyers and processors willing to be linked with dairy farmers
Magnitude of Impact	Moderate-Major	Moderate-Major	Moderate-Major	Minor-Moderate
Farmers' Current Coping Strategies	Farmers using locally available private service providers; open up waterways and introduce drainage to direct floods away from farms; some cooperatives have dairy hubs offering extension services	Opening up drainage to direct floods away from farms; preserving feeds before onset of flooding; planting crops not easily carried away by floods; stocking on high grounds; vaccinating prior to disease outbreaks; spray insect breeding sites to reduce biting insect population; partial or temporary relocation to higher camping sites like schools; de-silting of existing dams; relevant departments introducing early warning systems and advisories	Using temporal mitigation strategies e.g. filling gunny bags with sand to bridge impassable roads linking to bulking and storage centers; using readily-available modes of transportation that can negotiate poor roads; using alternative modes to deliver milk to collection centers	Using extension forums and charitable organizations or activities such as field days to promote their products; selling at local market; using available transport means to deliver products to market centers; bringing products closer to buyers
Potential Adaption Options	Having own kits at farm level for easy access and quality assurance; more cooperatives to adopt extension through dairy cooperatives; evacuate or dig dams to drain water from flooded areas, planning to relocate population near river banks and in low-lying areas away from flood-prone areas; linking to digital platforms for extension or online information, encouraging introduction of dairy hubs at producer organizations (POs) and cooperatives to offer extension services	Digging dams to store excess water for future use; relocating people from flood-prone areas; upscaling draining of flooded areas, planting suitable fodder crops; sinking dams in high flooding areas, constructing dykes, encouraging adherence to early warning systems and weather advisors; upscaling awareness creation and adopting technologies on disease control; reviewing existing policies and regulations on disease control; enrolling and implementing prevention and control strategies prior predisposing hazard occurrences	Investing in alternative transport modes that will help deliver milk to bulking and storage centers in time; lobbying for upgrading rural impassable roads to make transportation easier; using readily available modes of transportation; processors taking own initiatives in collaborating with government to repair their feeder roads affected by floods	Investing in electronic and digital platforms for promotion; enhancing using local extension forums such as field days, local markets; lobbying for repairing impassable roads that hinder product supplies to market; selling products to local markets; investing in transportation modes
Underlying Factors	Infrastructure: some rural farms are located in areas with poor road networks that become impassable during rainy seasons; biophysical factors: some rural farms are located in hilly areas with steep terrain making farms inaccessible during rainy seasons; economic factors: small-scale farmers have low purchasing power to afford costly inputs; policy factors: heavy taxes applied on most inputs or raw materials used on feeds making products costly for small-scale farmers; institutional factors: lack of know-how on affordable on-farm feed formulation	Institutional factors: lack of knowledge and skills on affordable farm feed formulations- even during scarcity; infrastructure: lack of machinery and equipment for feed preservation during seasons with adequate /excess feeds for use during scarcity; policy factors: heavy taxation on farm inputs and machinery making them costly for farmers with low purchasing power; sociocultural: farmers with fixed mindset against relocating from their ancestral land that may be prone to flooding; biophysical factors: geographical location and terrain of low lying areas make them more prone to flooding	Infrastructure: most roads in rural areas become impassable during rainy seasons; economic factors: better milking equipment costly to farmers with low purchasing power; policy factors: poor enforcement on using inappropriate equipment when handling milk leading to spillage and spoilage	Infrastructure: physical movement to promote dairy products and poor networks to encourage online/digital promotion is hindered by impassable roads; biophysical factors: unable to reach other markets because of physical location; policy factors: fluctuations of commodity prices due to prevailing market forces that could be mitigated by provision of subsidies to farmers and consumers

Figure 12: Climate variabilities and adaptation strategies across the value chains in Trans Nzoia County

5. Policies and Strategies on Climate Change

Policies addressing climate change and variability mainly operate at the national level (Table 3). However, counties are adopting the national policies to fit their circumstances. Trans Nzoia County is at an advanced stage in formulating its policy on climate change. This policy will ensure that 2% of the county budget will be allocated to climate risk management. There are also several national policies and strategies that revolve around the agricultural sector which have been adopted in Trans Nzoia County to address climate change.

Table 3: National policies targeting climate change adaptation and mitigation in Trans Nzoia County

Policy	Year	Policy objective(s) achieved at the county level	Interventions contributing to climate change adaptation and mitigation	Challenges and policy gaps
National Climate Finance Policy	2016	Establishment of mechanisms to mobilize climate finance	County Climate Change Fund regulations, currently at the draft stage	• Limited political goodwill • Weak coordination between public- and private-sector actors
National Agricultural Sector Extension Policy	2016	Provides guidance in addressing key sectoral issues in the delivery of extension services It also offers guidance on the role of the private sector and its modalities of providing extension	Technology transfer and knowledge sharing Linking farmers to other actors Devising and addressing funding modalities	• Declining human, capital and financial resources • Managing pluralistic extension service for effective service delivery • Institutional weakness in capacity building, technology development and dissemination
Irrigation Policy	2015	Expansion of land under irrigation and promotion irrigation in each sub-county	Increased area and more crops under irrigation using water-efficient technologies Water harvesting and storage	• Low rate of irrigation infrastructure development • Inadequate funding
Forest Policy	2015	Expansion and maintenance of tree and forest cover over at least 10 percent of the land area	Tree planting Agroforestry Plantation Establishment Livelihood Improvement Scheme (PELIS) Promotion of community participation in forest management and conservation Formation of Community Forest Associations	
National Cooperative Development Policy	2019	Creation and facilitation of an environment that promotes sustainable and competitive societies	Formation of producer organizations Awareness raising to increase membership in producer organizations Provision of a network of storage and distribution facilities for agricultural inputs such as seed, fertilizers, and equipment Aggregation of members' input requirements for cost-saving, centralized purchase that creates economies of scale	• Low capital investment • Governance and management challenges • Difficulties in attracting new members to join and retaining existing active members • Inability to embrace processing and value addition

Policy	Year	Policy objective(s) achieved at the county level	Interventions contributing to climate change adaptation and mitigation	Challenges and policy gaps
Environmental. Management and Coordination Act	1999	Supervision and coordination of all matters relating to the environment and implementation of environmental policies	Provision of a framework for an integrated approach to planning and sustainable management of environment and natural resources Awareness raising about the importance of environmental issues in Trans Nzoia County	
Water Policy	2012	Promotion of optimal, sustainable, and equitable development and use of water resources for livelihoods of Kenyans	Enhancements of storm water management and rainwater harvesting Progressive restoration and protection of ecological systems and biodiversity in strategic water catchments	

6. Institutional Capacity and Climate Change

Institutional resources and capacity are key to improving farmers' adaptive capacity and climate change resilience because they shape resource-use actions and outcomes. In Trans Nzoia County, many institutions are working on issues related to climate change, agriculture, water or food security: the government, private entities, non-governmental organizations, and community-based organizations. Their interventions include research and extension, early warning systems, capacity building, the provision of technology and technology transfer, enhancement of market linkages, financial and credit services, disease surveillance, and the provision of agro-inputs such as seeds, chicks, fertilizers, and pesticides (Table 4).

Table 4 : Institutions that are currently, supporting and implementing agricultural interventions in Trans Nzoia County

Off-farm services	Institutions	Specific interventions in Trans Nzoia County	Challenges
Research and extension services	Trans Nzoia directorates of agriculture,t, livestock, and cooperatives, and of veterinary services KALRO-Kitale Centre	On-farm demonstrations of new crop and livestock technologies, innovations, and management practices AI services Animal selections that suit different agroecological zones Varietal and breeds development	Poor coordination among the organizations that leads to duplication and overlap of roles and efforts
	Department of Energy, Water, Environment, and Natural Resources	Construction of dykes De-silting of dams Drilling of boreholes Construction of additional water-harvesting structures	
	KFS	Tree planting, agroforestry, and reforestation Promotion of community participation in forest management and conservation PELIS Advancement of conservation Protection of water catchment areas	
	National Environment Management Authority (NEMA)	Support for sustainable environmental management through integrating environmental considerations into development policies, plans, programs, and projects	
	Kenya Plant Inspectorate Service (KEPHIS)	Regulatory framework for adaptations such as improved crop seeds	

Off-farm services	Institutions	Specific interventions in Trans Nzoia County	Challenges
Climate information services and agro-weather advisories	Kenya Meteorological Department (KMD)	Weekly bulletins and seasonal weather forecasts in the local language via media channels such as local radio and TV stations, social media platforms like WhatsApp, and short message services through phones	
Early warning systems and Participatory Scenario Planning	KMD	Warnings about disasters like mudslides and landslides Support for planning of farm activities	
Non-financial subsidies for inputs like fertilizers, pesticides, and seeds	One Acre Fund	Provision of planting fertilizers, certified seeds, and training Financing to support on-farm activities and input supply	
	Trans Nzoia County Government	Subsidies for farm inputs like certified seeds	
	Unga Group Limited, Bidco, Ultravetis, Vital Animal Health, East Africa Seeds Co. Ltd., Kenya Seeds Co. Ltd., Western Seed Company, OSHO Chemicals, Murphy Chemicals Ltd., Bayer East Africa, and Baraka Fertilizers Ltd.	Distribution and sale of seeds, agro-chemicals, and other farm inputs Provision of training and demonstrations on the use of these inputs	
Financial services like rural credit schemes	Savings and Credit Cooperative Organizations	Input acquisition, financing, and support in obtaining farm and input supplies Marketing of produce	
	Agricultural Finance Corporation	Financing for input and farm equipment acquisition	
Market services, infrastructure, and linkages	New Kenya Cooperative Creameries Brookside NCPB	Marketing of produce Value addition	

7. Synthesis and Outlook

Agriculture is the economic mainstay of Trans Nzoia County in terms of income and food production. The sector is characterized by relatively high input use and mechanization. However, the sustainable growth of the agricultural sector is challenged by high input costs, low producer prices, inadequate extension services, insufficient storage and processing facilities, little or no value addition, and suboptimal markets and marketing infrastructure. This situation is aggravated by the adverse impacts of climate change and variation that have led to extreme temperatures, the emergence of new pests and diseases, and increased flooding incidence, all of which can contribute to diminished agricultural productivity.

Investments in adaptation methods could address the negative impacts of climate change. Examples include investments in water retention and control systems such as dams to prevent flooding. With deliberate efforts, agroforestry and farm forestry can be upscaled. Training in value addition will empower farmers to realize better returns from their enterprises. Alternative crops have been introduced for purposes of diversification, which enables farmers to avoid relying on crops that might prove too vulnerable to climate change and variability.

The increasing incidence of climate hazards calls for greater institutional capacity to respond to changes. Adequate budget provision to carry out climate risk management activities could be accompanied by relevant policies and interventions anchored in development plans. This combination of careful budgeting, policy, and planning can provide enabling frameworks to allow various stakeholders in climate risk management to work together on strategies that help farmers cope with climate change and variability. In addition, the Kenyan policy environment could be reviewed, and policies supporting poultry and dairy farming formulated where they do not exist, in collaboration with stakeholders.

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9. Acknowledgements

This study is the product of the Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MoALFC), with assistance from the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) and the Consultative Group on International Research (CGIAR) Research Programme on Climate Change, Agriculture, and Food Security (CCAFS), as part of the National Agricultural and Rural Inclusive Growth Project (NARIGP), supported by the World Bank (WB).

The document has been developed under the coordination of Evan Girvetz (Alliance of Bioversity-CIAT) and John Kimani (National Project Coordinator, NARIGP), under the technical leadership of Stephanie Jaquet and Caroline Mwongera with contributions from (in alphabetical order): Harold A.E. Achicanoy, Josky Embwaga, Alejandra Esquivel, Aniruddha Ghosh, Dorcas Jalang'o, Stella Kasura, Ivy Kinyua, Victor Mugo, Jessica Mukiri, Wilson Nguru, Fridah Nyakundi, Ruth Odhiambo, Julian Ramirez-Villegas

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We acknowledge the contribution of the NARIGP team: Mary Maingi, Judy Amadiva. We also express gratitude to the following institutions for providing information to this study:Livestock, Veterinary, Environment, Water, (Agricultural Sector Development Support Programme (ASDSP), Kenya Forest Service (KFS), Kenya Meteorological Department (KMD), National Environmental Management Authority (NEMA), Kenya Agricultural and Livestock Research Organization (KALRO), Kenya Plant Health Inspectorate Service (KEPHIS), Kenya Seed Company, Agricultural Development Corporation (ADC), CARE-Kenya, Climate Smart Agriculture Youth Network (CSAYN),, Chambers of commerce, , Kapsitwet Ogilgei Dairy Cooperative, Ushindi Poultry and Marketing Cooperative Society, Seum Leltei Youth Group.

This document should be cited as: MoALFC. 2021. Climate Risk Profile for TransNzoia County. Kenya County Climate Risk Profile Series. The Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MoALFC), Nairobi, Kenya.

10. Annexes

10.1 Glossary

Climate change: A change in the state of the climate that can be identified, for example, by using statistical tests, by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal process or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2018).

Climate risk: The potential for consequences when something of value is at stake and when the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the probability that hazardous events will occur or that trends will be multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazards (IPCC, 2018).

Climate hazard: The potential occurrence of a natural or human-induced physical event, trend, or impact that may cause loss of life, injury, or other health impacts, as well as damage and losses of property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC,2018).

Climate variability: Variations in the mean state and other statistics related to the climate, such as standard deviations or the occurrence of extremes, on all spatial and temporal scales beyond that of individual weather events (IPCC, 2018).

Greenhouse gases: Atmospheric gases responsible for causing global warming and climate change. The major GHCs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Less prevalent but very powerful greenhouse gases are hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (SF_6).

The Representative Concentration Pathways (RCPs): Four greenhouse gas concentration trajectories adopted by the IPCC for its AR5. The four RCPs – RCP2.6, RCP4.5, RCP6.0, and RCP8.5 – are named after a possible range of radiative forcing values in the year 2100 of 2.6, 4.5, 6.0, and 8.5 W/m2, respectively.

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